WESTINGHOUSE Engineer

JANUARY 1953

enlarged responsibility of Engineering

Westinghouse again presents a review of the recent activities of its scientists and engineers. As in previous years, it consists of short discussions of selected subjects. It is by no means complete—many interesting items have been omitted. But we believe the quantity and variety amply illustrate the different phases of today's technical activity and the more important trends in the production and use of energy.

Several trends are apparent. Some are new; certain old ones are continuing. The electrical ratings of the major generation and distribution apparatus continue to rise at an astonishing and undiminished rate. Automatic controls for process industries are increasingly numerous. The magnetic amplifier has, almost overnight, won a major place among electrical controls—and to a great extent is being used for tasks previously performed electronically or by rotating machines. For many applications aluminum is replacing copper, with worthwhile reductions in the annual requirements of copper, dictated largely by economics.

The most prominent trend, however, is the increasing caliber and content of engineering required for most power apparatus. This arises largely out of the fact that design requirements are becoming more exacting and manufacturing processes are becoming more complex, more integrated, with higher outputs, and with more rigid control of quality. For example, the engineering embodied in an electrical power system for aircraft today is far more than that contained in the simple plant, consisting of one or two d-c generators and elementary controls, for World War II planes. The regulating systems for two textile-fiber processing lines may look much alike, but the regulator for a man-made fiber plant, where speed regulation is held to one tenth of one percent, calls for far more engineering than the other where one-percent regulation is adequate. The amount of active materials per kva in an inner-cooled generator is about half that in a conventional machine—but the engineering man-hours are far more.

Thus the need for engineering is growing in two dimensions. The technical content of a given product is rising. And there are more and a wider variety of these engineering-consuming equipments. Superposed on this are the defense projects, most of which demand a high order of engineering. How this demand is to be met is a major problem, because the available supply of technical manpower has not increased in anything like the same ratio as the need, a situation intensified by the Armed Forces' demand for men.

It would be too much to say that this problem has been fully met. However, much has been done to increase engineering productivity. For example, a concerted effort has been made—and more can be done—to relieve trained engineers of work that can be performed by properly trained technicians. Programs are underway to give on-the-job training for high-school graduates that will give them semitechnical abilities and at the same time ease the burden on the corps of more highly trained engineers.

Analog and digital computers have become an indispensable factor in both design and application. They have saved countless hours of engineering time, and, in addition, have made possible a type of engineering analysis that either was not economical or possible before. This results in optimum designs.

Standardization programs have greatly reduced the total engineering load by curtailing the amount of time required when every job is custom engineered. Standardized steam turbines are an outstanding example. The proposed standards for network transformers and high-voltage bushings will also help in this direction.

Additional spur to the creative talents of the technical staff can come from special rewards for outstanding accomplishments and for patentable ideas of unusual merit. This tends to increase engineering fertility, and has proved beneficial.

Although the scientific and engineering staffs have been working under a considerable load and under some handicaps, the product as suggested by this review is, we believe, impressive. Progress has been registered along many fronts. In some cases these are improvements in long-established equipments or their use. In others, the developments are along the lines of new materials, entirely new devices, or new fields of application—suggestive of the broadening base of electrical engineering. We believe you will find this review both entertaining and of practical use.

A. C. MONTEITH
Vice President in Charge of Engineering

WESTINGHOUSE Engineer

VOLUME THIRTEEN JANUARY 1953 NUMBER ONE

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Published bimonthly (January, March, May, July, September, and November) by the Westinghouse Electric Corporation, Pittsburgh, Pa.

Subscriptions: Annual subscription price in the United States and possessions is $2.50; in Canada, $3.00; other countries, $3.00. Single copy, 50c. Address all communications to *Westinghouse* ENGINEER, P.O. Box 2278, 401 Liberty Ave., Pittsburgh 30, Pa.

Indexing and Microfilm: *Westinghouse* ENGINEER contents are regularly indexed in Industrial Arts Index. Reproductions of the magazine by years are available on positive microfilm from University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

THE WESTINGHOUSE ENGINEER IS PRINTED IN THE UNITED STATES BY THE LAKESIDE PRESS, CHICAGO, ILLINOIS

A 100 000-kw turbine generator installed in the Gorgas Station of the Alabama Power Company. At right is a 60 000-kw unit in the Gaudy Station of the New York State Electric and Gas Corp.

Turbines

Steam Turbines Continue Rapid Rate of Growth in Size and Numbers

THE two trends that have been outstanding on the power-generation scene since World War II continue. One is the extremely high rate of additions to generation capacity. Secondly, this trend continues with units of larger and larger size. In the year ending last August, Westinghouse undertook the construction of 47 turbine-generator units of 10 000 kw or larger. These total over three-million-kw capability. The average size of these machines for the electric-utility industry is 75 000 kw. Ten years ago this was the largest high-speed machine in service in the United States. Of these 47 machines, 15 have ratings 100 000 kw and over, of which 8 are at least 150 000 kw. For the past five years the rating of the largest 3600-rpm single-shaft machine under construction has increased yearly on the average of nearly one fifth. Last year it rose one fourth—from 200 000 kw to 250 000, of which rating two machines are being built for TVA for installation in 1955. Engineers see no reason why even this king-size figure can't be exceeded. The largest 3600-rpm single-shaft machine in service a year ago was one of 125 000 kw.

Manufacturing Facilities Expand Too—When factory expansion is necessary, seldom does an idle plant almost tailor-made for the purpose lie next door. But such was the fortune of the Westinghouse Steam Division. During War II a large plant was constructed next door for the production of steam turbines and gears for merchant-marine vessels. This plant has remained in a "moth-ball" state since the war's end. When enlarged manufacturing facilities were needed to keep up with the demand for utility turbines and to give additional space for new gas turbines, Westinghouse was able to make arrangements with the government to reopen the plant. It is being retooled for production of marine-propulsion units of all sizes and of electric-utility turbines of 10 000 kw and larger. Also it will make available additional facilities for the manufacture of gas turbines. This will be completed in a few months and will increase Westinghouse steam- and gas-turbine engineering and manufacturing facilities by about one half. Further increase in turbine-production facilities has been made possible by the addition of equipment at the Sunnyvale, California, plant to produce standardized turbines up through the 60 000-kw class.

Steam Conditions—The upper limits of steam conditions have not changed, but many more machines are being built for top temperatures and pressures. Westinghouse has built or has under construction 13 machines to use 1050-degree steam and one—a 185 000-kw unit for Burlington Station, Public Service Electric & Gas Company of New Jersey—will

take steam at 1100 degrees. This will be the first machine to use the 25-inch blade. A turbine inlet temperature of 1150 degrees, while coming, is probably several years away.

Pressures of 1450 and 1800 psig are common. A few will use steam at approximately 2400 pounds, which establishes no new record. Pressures probably will go higher. However, the need for them has been eased by the rapid adoption of reheat. Reheat returned to favor only about five years ago. Already the machine of 100 000 kw and larger without it is the exception because of the rising fuel cost.

Significant Units—While many installations, each with some element of technical interest, were made in the past 12 months, a few deserve special mention. The two machines of largest size were the 125 000-kw units, one in TVA's Johnsonville Station, and one in the Delaware Station of Philadelphia Electric. Both are tandem-compound, triple-flow, 3600-rpm units. Cross-compound machines are no longer common, although two for 150 000 kw are now being constructed.

Two years ago the Dow Chemical Company made news with a 30 000-kw, noncondensing, automatic double-bleeder turbine—the largest double-extraction turbine ever built. A second such unit is being furnished to Dow Chemical for its Midland, Michigan, operation. This same firm began the installation last year, at its Freeport, Texas, plant, of a 40 000-kw, single-extraction, condensing machine. This machine is arranged for automatic extraction.

Turbine and Steam-Plant Improvements—Several noteworthy items of technical progress have been aimed mostly at turbine simplification. One has to do with the mechanism for lifting inlet steam valves on high-temperature machines. The practice has been to provide a separate servomotor for each of the four valves in both steam chests. That meant eight servomotors and the oil piping for each. Now a construction has been devised that is suitable for 1050-degree machines. In it, all four valves are lifted by a single bar with one servomotor. This reduces the servomotors from eight to two, and the oil piping by a like amount.

Another simplification occurs at the interceptor valve. This valve has an important emergency protective role when a reheat turbine generator suddenly loses load. When this happens the main steam-inlet valves close, but there may be enough steam already in the turbine system, particularly in the reheater system, to cause the unloaded machine to overspeed. The interceptor valve must restrict the flow of this steam into the blade sections so that a safe speed is not exceeded. After this steam has been dissipated the interceptor must return the control to the main steam-inlet valves. A new inverted type of interceptor valve, employing a balanced-valve design, permits direct connection to the servomotor and eliminates elaborate linkage.

An important innovation is in the manner of cooling the parts of the turbine exposed to the hottest steam. The trick is to use steam itself to do the cooling. Steam enters, say, at 1100 degrees. After passing through the high-pressure element, it has cooled to about 700 degrees. Instead of sending this steam to the intermediate-pressure section as in the normal manner, this relatively "cool" steam is doubled back on itself and flows in passages over the zones carrying the steam at higher temperatures. Thus the temperature of the internal parts is reduced, while the outer wall is exposed to a uniform temperature of 700 degrees.

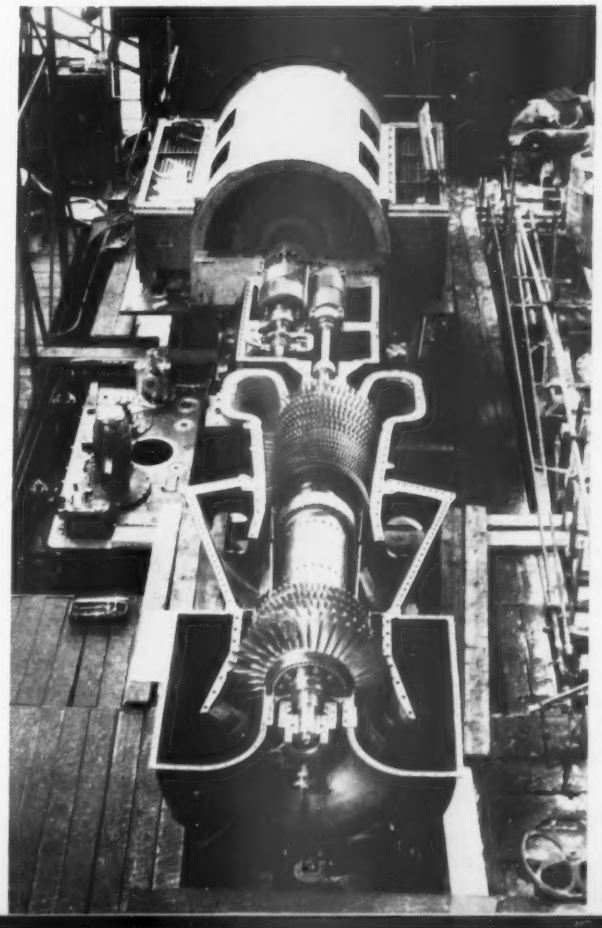
These lower metal temperatures greatly reduce the wall thickness, bolting size, and material requirements. The saving of material is important not only because of the weight reduction of the high-pressure element, but because of the economy of critical materials. The handling and tightening of large bolts during erection and maintenance periods are time consuming. The reduction of outer cylinder bolting diameter by about one half materially reduces the time consumed in assembly and dismantling.

Direct-Drive Oil-Relay Governor—An important simplification has come to mechanical oil-relay governors used on some industrial turbines. These have employed a gear arrangement and mechanical linkage to connect the flyball governor to the main shaft and the hydraulic control relay. Shaft-mounted flyballs and cup valves eliminate troubles with rotating and stationary speed-sensitive parts. A frictionless strap mounting permits use of tiny weights. The whole governor assembly is no larger than a fist. Light weight makes possible shaft mounting for high speed (5000 rpm) and wide speed range (better than two to one) without sacrifice of sensitivity. This construction—simple, small, and versatile—may also replace some other types of governors.

Feedwater Heaters and Pumps—Some simplification is being effected in that crowded mass of piping and equipment that lies, like tree roots, below the deceptively roomy turbine floor. Feedwater heaters are being placed inside the condenser neck. This makes the heaters and their piping less accessible, but saves space and piping complication. Typical of this construction are three low-pressure feedwater heaters installed in a single shell and contained within the neck of a condenser for a New York State utility.

To reduce turbine-foundation height, condensate pumps are made vertical instead of horizontal, and sunk into the basement floor beside the condenser. Reduces the height by several feet and reduces plant cost.

A 5000-kw gas-turbine generator on test. The unit was installed last fall on the power system of the West Texas Utilities Company.



Load Control—Different situations requiring new turbine control continually arise. One, chosen simply as typical, is that for three 7500-kw waste-heat turbines high in the Chilean Andes at a copper mine and smelter. Supplementing the local power plant, energy is brought in over a long tie line. Because of the mountainous terrain this line is subject to outage, yet it is imperative that certain synchronous motors at the smelter not shut down or pull out of step should the tie line open. A special ultra-fast magnetic-amplifier load-sensing device was developed for this situation. When the tie line fails, it causes all but the essential load to be dropped. Then, as the turbines can pick up some or all of the dropped load, the system is allowed to do so. The control holds speed variation during these transient conditions to within one-half cycle.

The Expanding Gas-Turbine Business

In September, 1952, a 5000-kw gas-turbine generator began delivering power to the system of the West Texas Utilities Company, which covers a wide strip of Texas 400 miles long, from Mexico to Oklahoma. This kilowatt-producing gas-turbine unit rests, almost literally, on top of natural-gas wells (although it can burn distillate oil with ease). It provides much needed power for the rapidly expanding irrigation systems of Texas.

This unit is the simple, open-cycle type and is but 41 feet long and 12 wide. It sets new standards for simple construction and accessibility of parts. All hot, high-pressure bearing seals have been eliminated. No bearings are located within hot duct work. The two bearings are part of the main frame to give maximum rigidity. They are accessible from the ends of the machine. The six combustors project at an angle into the machine, so that their outer ends are exposed. Hence, they can be individually removed after their covers have been taken off. The machine is split along the horizontal so that the top cover can be removed as a single piece.

The unit, being the prototype, was extensively tested before leaving the factory. The thermal efficiency is about one fifth better than the pair of 2000-hp units that preceded it and now operating in a locomotive. The noise level is low; noise suppressors have been found to be unnecessary. Vibration, likewise, is insignificant.

The unit is truly a packaged power plant. All electrical connections terminate in a cubicle mounted on the oil reservoir, which, too, is an integral part of the package. All connections are made on the unit. The power plant is shipped as two pieces. The generator and gear are one; the gas turbine, the other.

Because the unit is compact and lends itself to a self-contained power package, the U. S. Army has purchased an identical unit for installation on railroad cars for use following some disaster or during an emergency. The power plant will occupy one car; the transformer, switching, protective, and control equipment, a second car.

Late last year tests began on a 5000-hp gas turbine to drive a gas-line compressor. It comprises two turbines on separate shafts. One turbine drives the air compressor, the other turbine drives the load. This arrangement allows operation of the power turbine over the entire speed range. A regenerator raises the efficiency by about 20 percent.

A much larger, more efficient gas-turbine power plant is under construction for the Public Service Company of Oklahoma. It will deliver 15 000 kw. This unit has two shafts. The high-pressure turbine drives the electric generator and high-pressure compressor. The low-pressure turbine, on the second shaft, drives the low-pressure compressor. In addition to regenerators, the unit has intercoolers between the two compressor stages. This arrangement gives the unit an efficiency equal to that of a comparable modern steam plant.

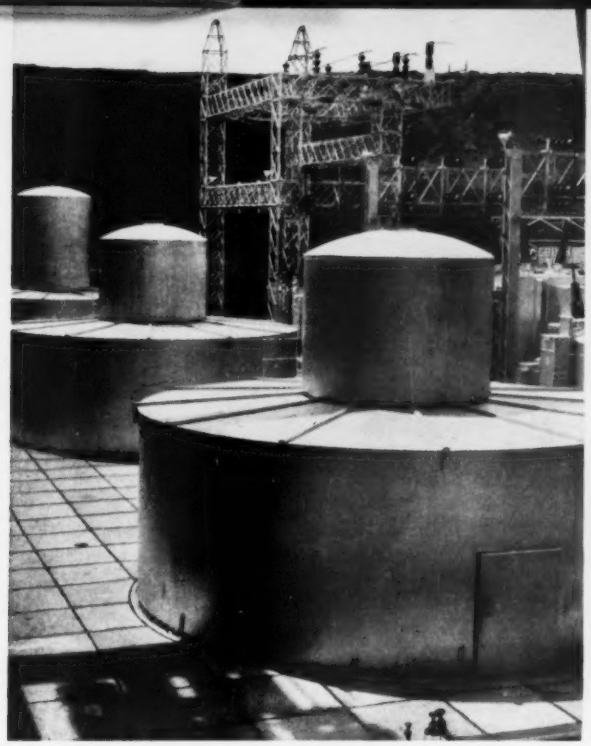
The gas-turbine art is still young. A great deal of fundamental development work continues. Some of it centers around the combustion of different fuels. Combustors have been developed to burn selected cheap residual fuels.

Considerable effort is being put forth to raise gas-turbine temperature, in order to win the improved efficiencies afforded by higher operating temperatures. The answer seems to be in the direction of better cooling of turbine blades and other parts exposed to combustion gases. Better cooling offers the hope of higher temperatures, longer life, and possibly even the use of less critical materials. Development of ceramic coatings for hot-metal parts shows considerable promise of reducing the amount of scarce materials used.

Generators

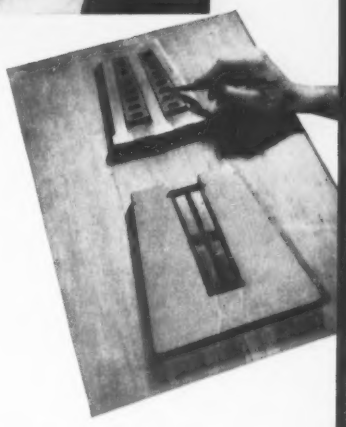
Cutting Generator Testing from Weeks to Days

Testing a large turbine generator has been a major undertaking, consuming several weeks. With the construction of the new manufacturing aisle at East Pittsburgh, this time is greatly reduced. The rotor, after seasoning and balancing in the new rig, is assembled in the frame and moved back to the test pit for final balancing, temperature checks, and many electrical tests. The pit contains a set of bus connections on wheels, oil lines, pumps, filters, and coolers, which are all easily connected to the generator. Piping time, which with rigid piping previously used ran to 300 or 400 hours, has been cut to half by the use of flexible hose. Instead of loading a generator onto the power-house system, load is provided by adjustable reactors. This system gives better control of generator loading.



The Idaho Power Company's Bliss power plant serves Idaho's new phosphate industry. Three 25 000-kva outdoor-type generators are connected to a 138-kv line through three 23 000/28 750-kva, three-phase transformers. Two generators are base-load units, while the third, in the background, is a Kaplan variable-pitch waterwheel, used to carry peak loads. The control for the adjustable runners accounts for the extra high dome on that machine.

The first waterwheel generator to be provided with Thermalastic insulation is a 29 000-kva Alabama Power Co. unit rewound at Jordan Dam.



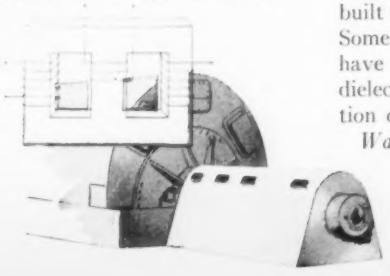
Extensive shop tests indicate that the promised 50 percent increase in generator capacity by inner cooling will be realized. Five machines of 100 000 kw or larger, including two of 250 megawatts, under construction at East Pittsburgh will have hollow coils in both rotor and stator. At right are full-size rotor and stator coils in cross-section with the normal air gap.

New Synchronous-Machine Voltage-Regulating System Is Reliable, Simple

WHEN IT comes to the voltage-regulating system for synchronous machines, engineers won't rest until they have achieved the ultimate in three regards: simplicity, reliability, and performance. Not that voltage-regulating systems have had a habit of letting them down. In fact reliability of these systems has been nothing short of remarkable, which indeed it must be because a central-station generating unit is expected to run uninterruptedly for months, even years. A good operating record notwithstanding, engineers simply don't relish the idea of having the continued operation of a huge, costly machine dependent on the faithful performance of small devices with moving parts or devices having limited life. With the appearance of reliable magnetic amplifiers, regulating-system design engineers saw their opportunity—and took it.

The system consists of four main elements—all static. One is a reference component; and the second a compensating and limiting circuit; the third and fourth are an input Magamp and a power Magamp. This system works in conjunction with a main exciter that has two separately excited control fields; and one self-excited field that is set manually and serves to provide a base excitation voltage for the synchronous machine.

The synchronous-machine terminal voltage, as modified by the compensating circuit, is supplied to the input Magamp, where it is compared with the reference quantity. Any deviation of the terminal voltage from its normal regulated value causes an error signal, which is amplified in the input Magamp and supplied to the power Magamp. The power Magamp includes two magnetic amplifiers serving the buck and boost control fields.



The a-c power supply to the reference element, the input Magamp and the power Magamp, is a permanent-magnet a-c generator operating at 420 cycles, giving the regulating system a faster response and smaller magnetic-amplifier reactors than would a 60-cycle supply. Test results show the Magamp system to be faster in response than any known regulating system employing a rotating-amplifier pilot exciter, because of the short time delay of the magnetic amplifier.

Progress with Rotating-Machine Insulation

TWO YEARS ago a radically new coil insulation for high-voltage rotating machines was introduced. It was comprised of mica and solventless synthetic resins. Already 100 large generators totaling 5 million kva have been built or rebuilt using this Thermalastic solventless synthetic insulation. Some machines have been in service three years. The results have fully supported the anticipated advantages: higher dielectric strength, better moisture resistance, and elimination of tape-separation problems on long generator coils.

Waterwheel Generators—Thermalastic insulation was origi-

nally available only for half coils (i.e., coils built and installed one side at a time) used in high-speed turbine generators. Use on the full coils of waterwheel generators presented a different problem because of their larger dimension. New facilities were required. Extensive new facilities for the impregnation of coils used in waterwheel-type machines with this new synthetic-resin insulation will be completed in a few months at East Pittsburgh.

Field testing of generator insulation is now in its third year. Some 10 million kva of machines in all kinds of plants—both public utility and industrial—and in all parts of the United States have been so checked. The merits of periodic testing of machines in service are being rapidly accepted in industry. In fact, a generator-insulation maintenance guide incorporating the techniques introduced by Westinghouse in 1949 has been prepared by an AIEE subcommittee.

The efficacy of periodic testing in a given case is impossible to prove, just as one can never know whose lives are saved by an accident-prevention campaign. However, it is significant that no machine tested and passed by these methods subsequently failed in service. On the other hand, several incipient weaknesses were disclosed—weaknesses that, if uncorrected, could well have led to failure both costly and inopportune as to time of occurrence.

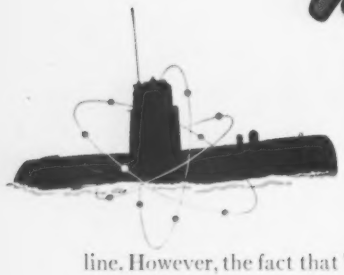
Hydrogen, Enemy of Thrust Bearings

ANY RELATION between tin cans and the performance of a mighty waterwheel generator is obscure. But there is one! One of the factors affecting the amount of hydrogen in commercial steel is the moisture present in rust on tin cans or other scrap used to produce the steel. Hydrogen in the steel used to manufacture babbitted thrust-bearing shoes may slowly ooze to the steel-babbitt interface to cause blistering.

Commercial steel can contain a surprising amount of hydrogen; at normal conditions it may be equivalent to 75 percent of the volume of the steel. At ambient or machine operating temperatures, hydrogen diffuses to the surface slowly—but diffuse it will. When it reaches the babbitted surface, it is blocked because tin and lead do not readily pass the hydrogen. The trapped hydrogen builds up a terrific pressure, perhaps in excess of 100 000 psi, ample to cause cracks in steel forgings and blisters in babbitt.

To forestall any difficulty from this source, the steel used for thrust bearings is given a carefully controlled and prolonged treatment to reduce the hydrogen content to a safe level. In addition to the hydrogen-relief treatment, a design change in the thrust-bearing shoes has been made to aid further in the escape of hydrogen.

Nuclear Power



Nuclear-Energy Power Plants

WE ARE certainly a long way from producing nuclear power plants on a production line. However, the fact that Westinghouse has under construction or design three of these plants of major size gives some definition about the present status of the science of controlled nuclear energy. One of these plants was referred to last year and is a prototype that could be installed in a submarine. Mark I is a full-size working model of the submarine plant at the National Reactor Testing Station near Arco, Idaho.

The second plant is known as Mark II, and manufacture has been started on many of the components. The submarine *Nautilus*, for which the keel was laid by the Electric Boat Company last July, will be the first submarine to receive this revolutionary new type of power plant. In the reactors for Mark I and Mark II, water is both the moderator and the primary coolant fluid. In the *Nautilus*, nuclear energy will be applied for large-scale controlled power utilization for the first time. This will result in an around-the-world submarine.

The third project concerns the design and development of another nuclear power plant many times larger than those mentioned above. It is planned that this power plant shall be suitable to power major naval vessels, such as aircraft carriers. However, it could well be a forerunner of the reactors which can be used to produce useful power, including electricity for homes and industry.

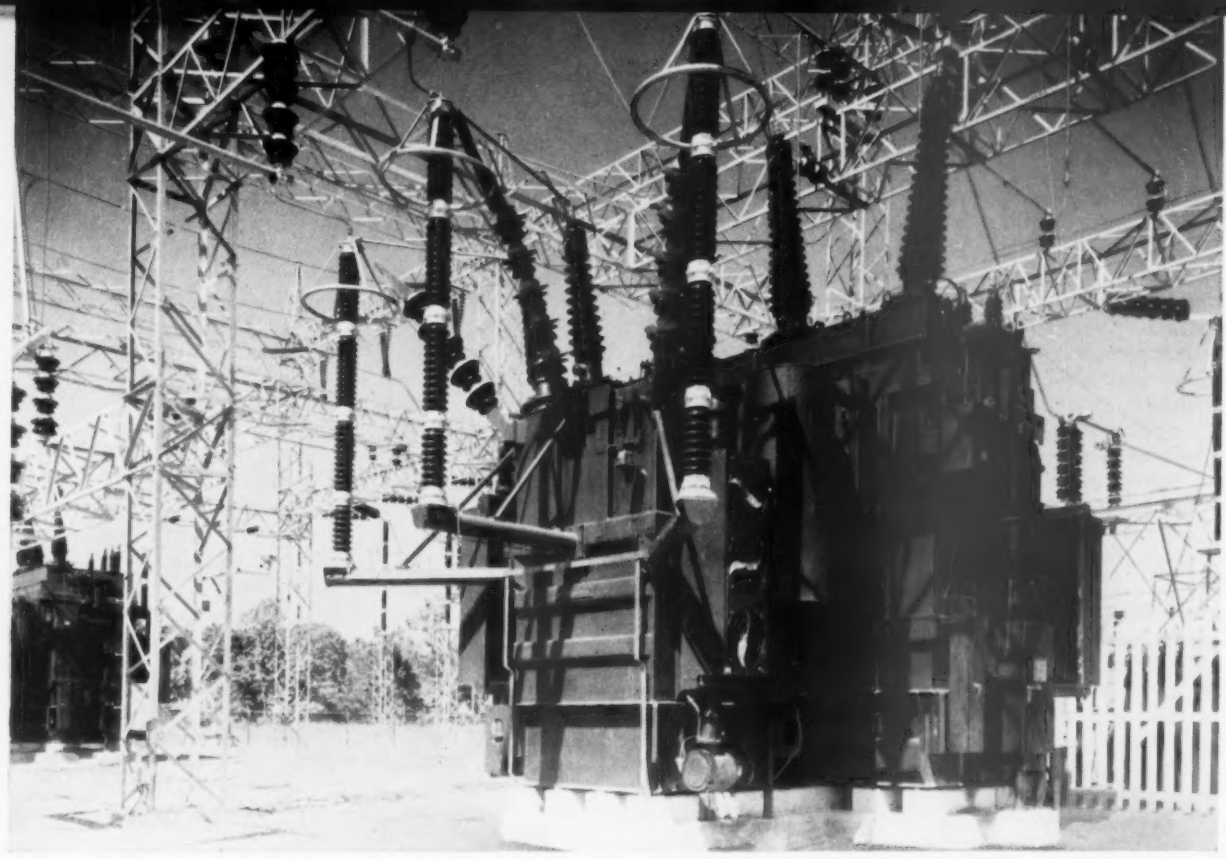
Canned Motors

MOTORS driving hot-water circulating pumps for the nuclear reactor are, literally, canned. The squirrel-cage rotor is contained in a shrink-fit jacket of steel. It turns within a stator that likewise is fully enclosed in stainless steel. In this type of a motor, the term "air gap" cannot be used as it is a combination of water and two layers of metal. Both the stator and the rotor are encased in stainless steel, and the space between is filled with flowing hot water—the same fluid that is being pumped through the reactor circuit.

As with most of the components of the reactor circuit, leakage must be small. Hence the motors cannot drive the pumps through seals. The rotor must be contained within the fluid circuit—and obviously is continuously exposed to water that is hot both as to temperature and radioactivity. To prove tightness, the stator enclosure is tested with the most sensitive leak detector obtainable. The space to be occupied by the rotor is filled with helium under a high pressure and with the stator volume evacuated. The bearings also are inside the stator and are lubricated by water.

The motors are built in several sizes. As if these many unusual requirements were not enough, the whole packaged unit—motor and pump built integral with it—must pass the Navy test for high shock. One unit is presently undergoing shock tests and has to date survived five blows of relatively severe intensity without any visible or operational damage. A smaller unit has been running for 13 000 hours continuously (1½ years) under conditions of full load, operating temperature, and pressure.

For additional sidelights on nuclear-power development, see inside back cover.



One of two 150 000-kva autotransformers on the 230-kv system of the Central Illinois Public Service Company, Joppa substation.

Transformers

What! Bigger Power Transformers Again!

SPEAKING of power transformers, this engineering review five years ago—January, 1948—said the following:

"The 105 000-kva, 69-kv units for Philadelphia Electric Company, the 83 333-kva, 220-kv units for Bonneville Power Administration, and the 50 000-kva, 132-kv units for Consolidated Edison Company all set new records for size in their respective classes."

Then in January, 1949, this was said:

"A 110 000-kva, 3-phase transformer is in service on the Buffalo-Niagara System. Soon to be installed is a 145 000-kva, 3-phase unit for Detroit Edison. This is the largest transformer (electrically and physically) ever shipped as a unit, complete except for bushings and radiators."

More, likewise, just a year ago:

"Last spring the Detroit Edison Company asked Westinghouse to build not one but four, rated at 190 000 kva. Except for bushings and radiators, each will be shipped factory-assembled as a single unit without oil."

Thus each year power transformer engineers break all previous electrical-capacity records. Not by just a little, but by a lot. And each year it is logical to assume that the ceiling of physical size—set by transportation limits—is being closely approached, if not actually reached.

Now we come to 1952. Last midsummer work began on a pair of 220 000-kva transformers, and later in the year engineers were actively at work preparing preliminary estimates on six 250 000-kva transformers—and, believe it, two units of 300 000 kva.

What always is astonishing is that it is still possible to ship these giants in their own tanks. No radical change in design principles has been found necessary. No need for change is foreseen for the near future. Several factors, of course, have come along to help push back the ultimate limit. The form-fit tank, with its walls closely fitting the core and coils, and the fact that such a unit can be shipped on its side, have helped immeasurably. The new high-capacity, drop-center cars made available by the railroads have been a factor. In the case of the larger units, the auxiliaries, such as radiators and tap changers can be easily shipped separately.

The year past, as far as power transformers are concerned, was also otherwise noteworthy. Work was well along on 15 transformers of a higher voltage rating than were before undertaken in the United States. These units are for the 330-kv system of the American Gas and Electric Company. This marks the first time the 287-kv operating voltage, set about 20 years ago on the lines from Hoover Dam, has been exceeded. These units will follow insulation and design techniques proved by the experience with the 500-kv test units built for the high-voltage experiments at Tidd Station.

The first of the two 83 333-kva mobile transformers reached its destination on the Bonneville Power System before year's end. This was also true of the first of the four 190 000-kva water-cooled three-phase transformers to be installed by the Detroit Edison Company.

Nearing completion is the first vapor-cooled transformer for commercial service. It is a 500-kva network unit for submersible service on the system of the Consolidated Edison Company of New York. It is an experimental unit on which actual service will be obtained to provide information needed by designers before this principle of vapor cooling can be extended.

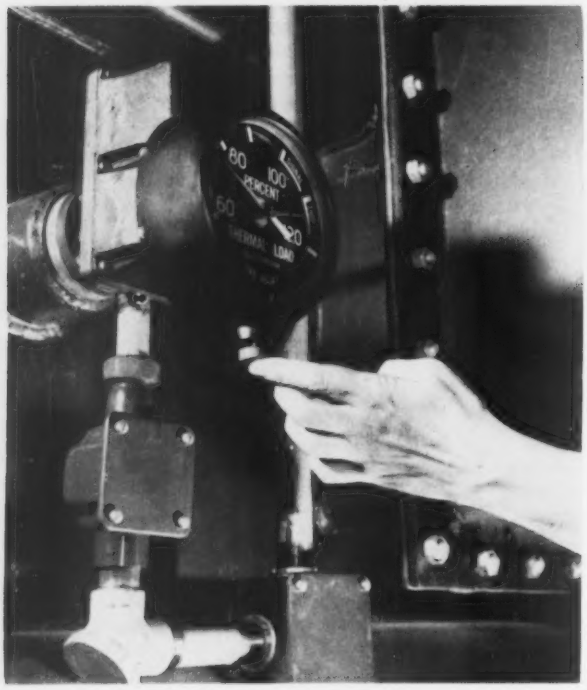
Better No-Load Tap-Changer Mechanisms

PARALLEL conductors carrying current in the same direction are drawn together as a result of the interaction of the two magnetic fields. This fundamental principle of physics is used in a new tap-changer mechanism to provide a vastly improved contact structure having longer life. In the usual tap-changer device, contact is made by forcing a metal wedge between fingers pressed tightly together by spring pressure. With this arrangement a short-circuit tends to open the contact.

In the new no-load tap changer (WSB) the stationary contacts are vertical blunt-nose pins about ¼ inch in diameter. The moving contacts consist of two short metal bars supported from the tap-changer mechanism by flat, spring-steel straps. When the geneva gear operates to establish a new tap contact these bars are lowered vertically around the stationary pins. The bars are shaped to fit snugly around the pins. The conducting paths are arranged so that current through the contact causes the bars, by interaction of the fields, to grip the pins tighter. Thus electrical forces are made to do the work of establishing a firm contact. The result is a contact that is improved rather than blown open by a short circuit. With this system the spring pressure need be enough only to insure the desirable contact-wiping action with each operation. Switch operation thereby requires little physical effort. Short-circuit tests prove that this construction can withstand a current of 80 000 amperes without blowing apart or burning a contact. This is probably four or five times more than is possible with conventional constructions. The 100- and 200-ampere (continuous rating) models have reached the production stage. Higher ratings are expected to follow.

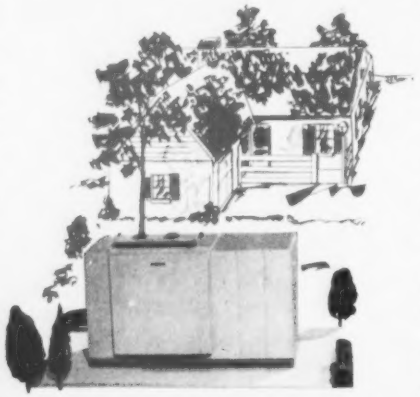
Shielded Tap-Changer Shafts—The judicious use of a small amount of crepe paper has resulted in shortening the shafts of no-load tap changers on high-voltage transformers by nearly half. For some time Westinghouse has used shields (somewhat like the arcing rings seen on arresters) on high-voltage tap changers. These distribute the electrical stress over the tap-changer shaft so that its strength to impulse voltages is greatly enhanced. Now, in addition, the metal rings are wrapped in insulating paper, which greatly reduces the clearances needed to withstand the high 60-cycle and surge voltages. Thus, for example, the Micarta shaft on a 220-kv tap changer was 40 inches long. The new one is but 20 inches.

From this instrument an operator can judge whether the transformer is thermally overloaded or can assume additional load.



No Need to Fence This One in

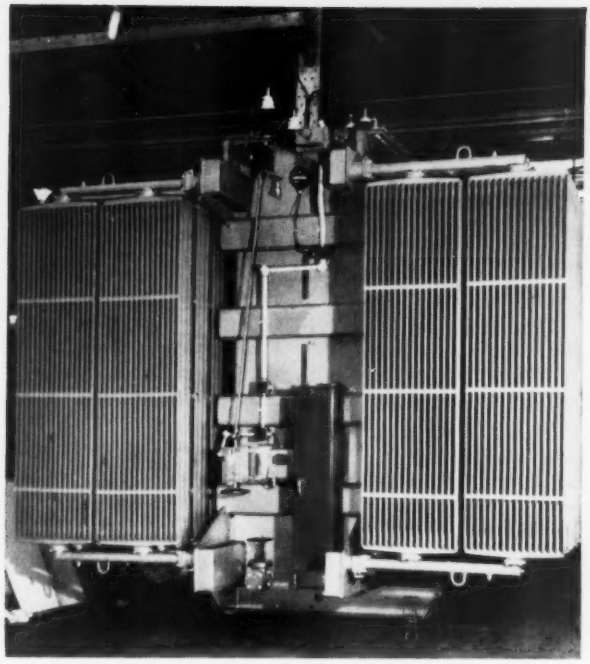
A FENCE around a unit substation in a residential neighborhood provides a good degree of safety against accidental contact with energized elements. But, no fence can guarantee absolute safety against the contrivings of mischievous youngsters. Also, a fence is no object of beauty, in spite of the appeal given by the cartoons in the advertisements of a well-known fence maker showing the frustrations of Butch and his pal. All this has led engineers to design a new single-feeder substation (the CSP power transformer), which is so thoroughly safe that no fence is required. All power leads enter by underground cable. Even the cooling radiators are enclosed. A streamlined housing integral with the transformer contains isolating switches, disconnecting switches, lightning arresters, and provision for connection to a mobile substation. Everything is completely dead-front—even to the most ingenious of small boys. A model of this substation is shown at left.



A Visual Indication of Transformer Condition

IF A power transformer isn't worked to the limit the fault won't lie with the design engineer. He is equally anxious that the transformer not be overloaded so heavily or for so long that its life is seriously shortened. Over the years he has provided devices to permit maximum safe loading. Now he has a new auxiliary that further helps keep the transformer loaded to the hilt. Transformers have, for several years, been provided with a relay (such as the TRO) that allows the transformer to carry load up to its safe limit and then give appropriate warning of danger. Finally, if the notice goes unheeded, the relay acts directly to relieve the transformer of the load. In making its "decisions" the relay takes into account ambient temperature, actual copper temperature, and recent load history. This has worked fine.

This relay now has an "assistant." It is a direct-reading indicator that gives the station operator a visual indication of the state of affairs so that he knows whether more load can or cannot be safely added. The gauge is marked in percent, 100 meaning that the present and recent loads, and ambient temperature are such that the transformer is fully loaded thermally. When the indicator moves through 100, representing an



This 9000-kva transformer for an aluminum plant is almost hidden by its radiators. It is self-cooled and hence has a large amount of radiating surface. Fans are omitted for maintenance reasons.

acceptable overload, the alarm is given; at 110, the relay trips. When the needle stands at less than 100 the operator knows he has load margin and roughly how much. The indicator has a second manually reset pointer, which stands at the highest needle position reached since last reset.

Aluminum in Reactors and Transformers

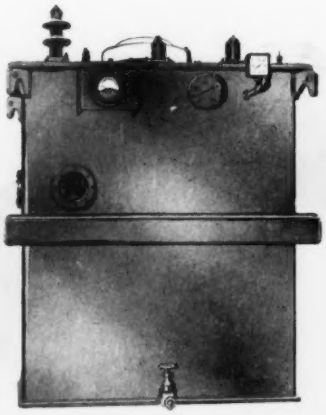
THE current-limiting reactor is one device where the switch from copper to aluminum has engineering benefits beyond the saving of copper. And that saving is considerable. Even the dry-type reactor of average size contains about 800 pounds of copper; a large one has about 4000 pounds. A large oil-immersed reactor may require nearly five tons of copper. Westinghouse, by developing reactors to use aluminum, will save some 200 tons of copper per year.

An aluminum-wound reactor weighs about one fourth less than its copper counterpart. Also, a normally undesirable property of aluminum can be turned in this apparatus to advantage. This is the fact that aluminum oxidizes instantly on contact with the air—a characteristic that is usually a headache. Aluminum oxide is a fair electrical insulator. Thus in aluminum-wound reactors where only separation is needed, it is not necessary to apply insulation between strands to cut down eddy-current losses. In copper-cable reactors alternate layers of strands have been enameled.

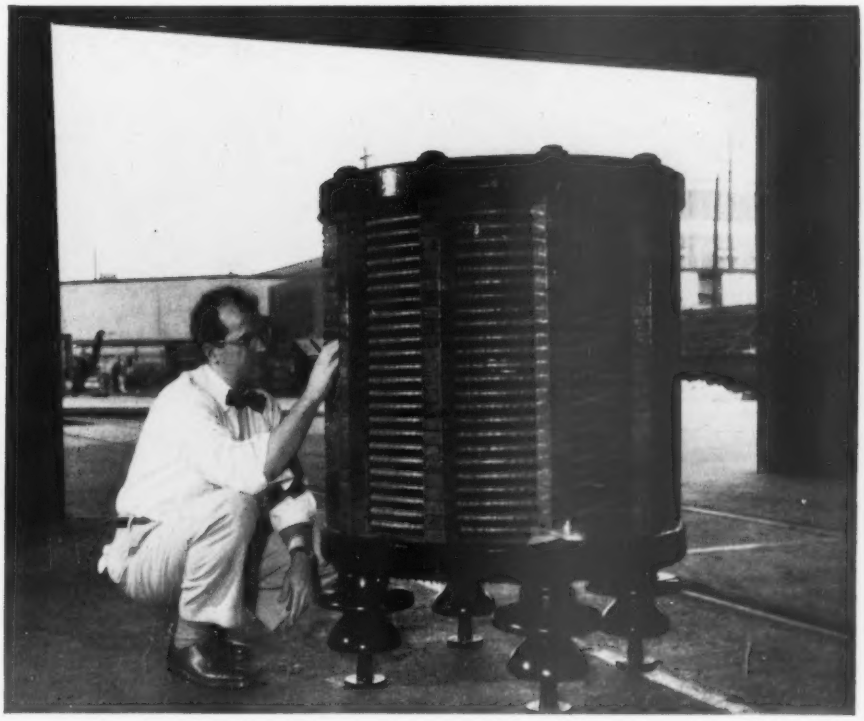
The lesser strength of aluminum, however, and the somewhat greater thermal expansion of aluminum by comparison with copper do have to be considered in the design. Requires more supporting columns and bracing.

Aluminum in Dry-Type Power Transformers—Experience with aluminum conductors is also being obtained in the ASL, dry-type power transformers. For about a year production units in limited numbers have been manufactured. The electrical performances of aluminum and copper transformers are identical. In dry-type transformers, aluminum windings weigh about half as much as copper. The iron is from seven to ten percent more. Overall weight is from two to five percent less.

Aluminum appears to have more justification in dry-type than in oil-filled transformers. This is because a dry-type transformer has relatively large insulation clearances and the increase in conductor sizes has less effect on the over-



The sealed, dry-type ASL transformer has proved its worth in service. In 1950, some 30 of the 1250-kw, three-phase units were built for New York City. Last year work was begun on the construction of 30 more.



This large current-limiting reactor has aluminum windings.

all size than when oil is used for transformer insulation.

The construction of dry-type transformers with aluminum coils involves no particular manufacturing difficulties. Aluminum-strap conductors are covered with fiber glass, using the same process as for copper. All joints in windings, leads, and busbars are either welded or bolted. Welded joints are arc welded under inert gas. Bolted joints, which are kept to a minimum, are silver plated and bolted with cadmium-plated steel bolts. To maintain high contact pressure, and distribute the stress in the aluminum, spring washers are used on the bolts. All joints are varnish covered, which, with the indoor application, adequately protects them from moisture. Use of aluminum results in a slight weight reduction.

Standardization Is Coming to Bushings

ANOTHER major electrical device is coming under the wing of standardization. This is the high-voltage bushing for outdoor transformers and circuit breakers. Committees have been at work drawing up specifications that will make the bushings of all manufacturers interchangeable. These standards—not yet fully agreed upon—apply to the bushings for 23, 34.5, 46, and 69 kv, and tentatively provide three lengths for each of three current ratings: 400, 800, and 1200 amperes. The standards deal particularly with uniform mounting dimensions, but in addition provide a common threaded connector on the upper terminal. This permits a power company to purchase and stock one type of device for terminating its lines.

Standardization is looked upon as bringing to this class of apparatus the same benefits it has in other fields, i.e., interchangeability, fewer spares to stock, quicker delivery from the manufacturer, and less chance of delay in obtaining the right bushing in an emergency.

Circuit Interruption

Larger Ratings for Oil Breakers

WITH VOLTAGES and interrupting-capacity requirements rising, the dead-tank oil circuit breaker continues to receive the nod as the preferred circuit-interrupting device. Interrupters of the multi-flow De-ion grid type have been designed for voltages up to 345 kv, similar to the large number built for 10-million kva at 230 kv, but with the necessary increase in insulation. These higher voltages employ the Watch-Case type of tank. The amount of oil required by comparison with the conventional cylindrical tank is greatly reduced. By this and other developments, the amount of oil per kva for dead-tank breakers has been reduced to one twelfth of that needed ten years ago.

Last year the first of the 10-million-kva breakers at 138 kv were produced. By comparison with the 10-million, 220-kv breakers, which were the first of the 10-million-kva group, these breakers must handle 60 percent more current. This larger current greatly magnifies the circuit-interruption problem, but this has been met with no fundamental change in current-interrupter principle.

The One, Two Punch for Capacitor Switching

ONE OF the toughest switching jobs is in connection with banks of capacitors. With parallel banks, the surge current becomes high with large capacitances discharging into

Left, one pole of a 10-mva, 138-kv breaker, and, below, one pole of a 15-mva, 345-kv breaker.

each other through circuits of extremely low impedance. Under switching conditions the current can rise to a hundred times normal in two thousandths of a 60-cycle wave because the natural frequency of the circuit is high. Voltages, too, can reach several times normal. To reduce these disturbances, breakers may switch the banks in two steps, the first step inserting a fixed resistance.

The resistances used in the past have been fairly high. Recent studies, supported by tests in the high-power laboratory, however, have indicated that a resistance of low ohmic value is better than a high resistance. It limits the transient voltages and currents to relatively low values. Thus, when restriking does occur with large potential differences between capacitor banks the circuit is hypercritically damped. The lower resistances pass more current and must, of course, be sturdier. Eight such capacitor banks, seven at 46 kv and one at 34.5 kv, have been so equipped.

Outdoor Oil Breaker Uses One Tank Instead of Three

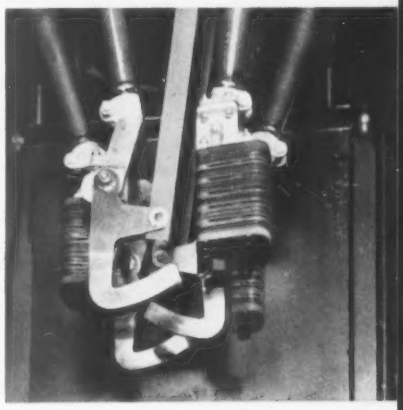
LOW-CAPACITY outdoor oil circuit breakers for 14.4- and 23-kv service have undergone significant changes. The most evident is in the tank. Instead of the traditional three-tank arrangement, all three poles are contained in a single tank, which is new for outdoor service.

In this breaker a single, dome-shaped top of steel plate $\frac{5}{16}$ inch thick supports all six bushings, the interrupter mechanism, the oil, and the case. To inspect or service the breaker, lowering a single tank exposes all three poles simultaneously. A new interrupter support makes contact fingers more accessible. The floor space required is somewhat reduced. This is particularly true for the reclosing units because the single, common housing requires working access from one side only.

A new design of interrupter is also used. One enlarged interrupter per pole gives the breaker adequate short-circuit capacity. The moving contact is hinged at one end. The other end makes contact within the single interrupter. The operating levers within the tank are simpler than in a design requiring straight-line motion of the moving contact.

The frame height is such that all live parts meet the National Safety Code requirements for height above ground for this voltage class.

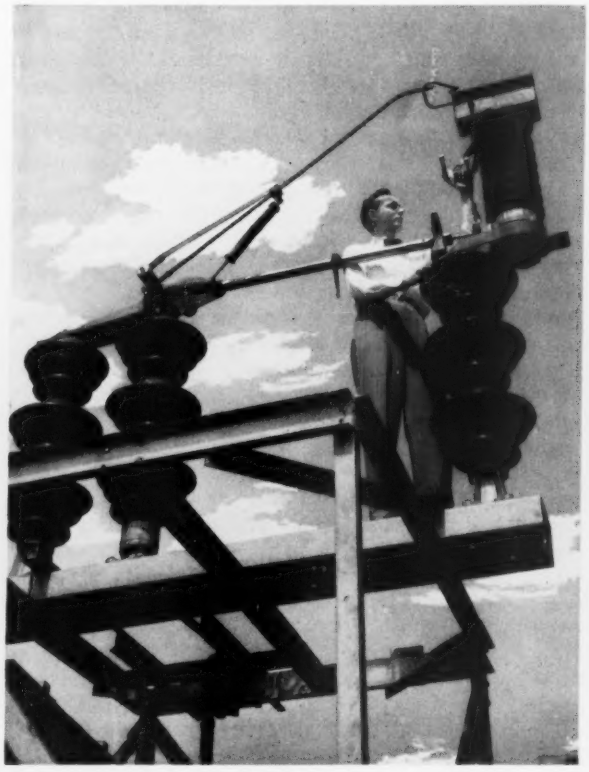
A single housing encloses the solenoid operating mechanism and associated control, and provision is also made in the housing for mounting a "package" reclosing protective relay panel. The standard panel carries the reclosing relay, protective relays, ammeters and control switch.



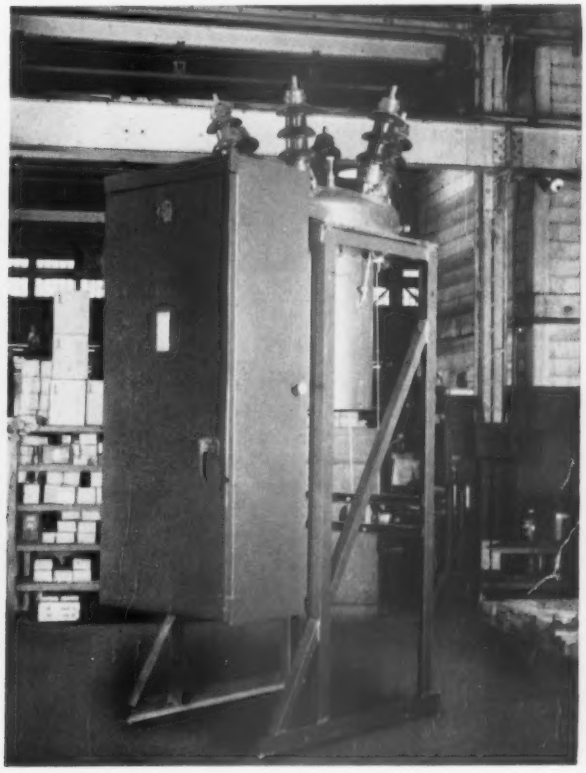
A three-phase interrupter.

Additional equipment as desired can be added to larger panels. Easily accessible terminal blocks are provided for the current transformer leads and for the operating control and power leads. The wiring will include the suggestions contained in the standardization program of the joint committee of operators and manufacturers.

A load-break switch with a gas-filled circuit interrupter.



All three poles of a new outdoor oil breaker are in a single tank.



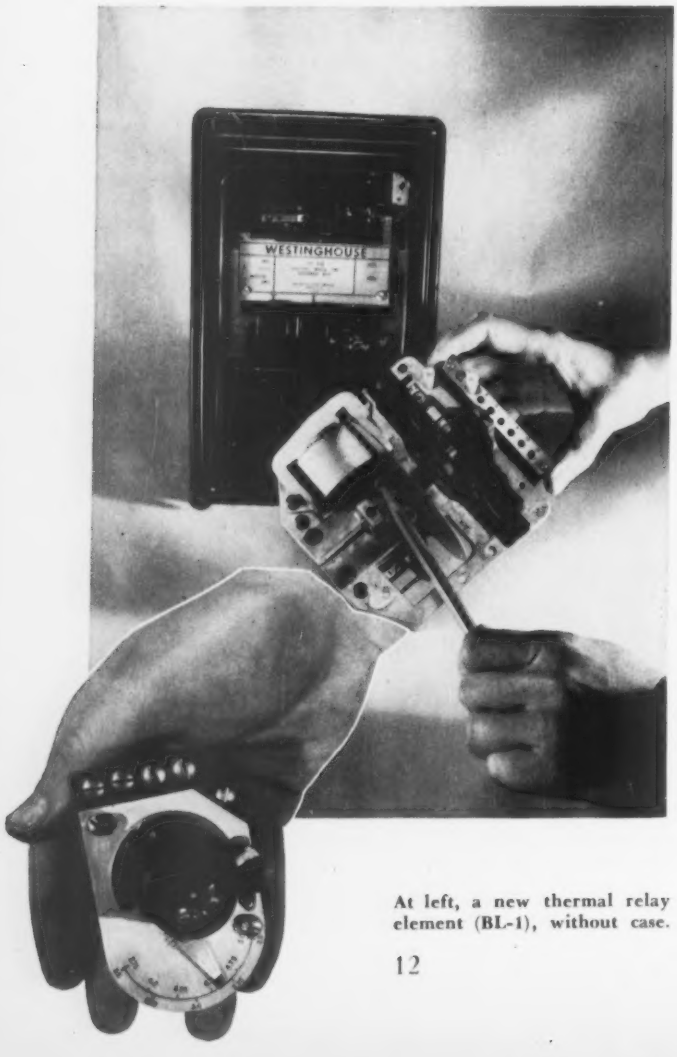
A New Gas—A Smaller Interrupter

THE SWITCHGEAR "ball club" has been missing a player in center field. Between the area covered by the disconnecting switch playing left field, say, and that well tended by the circuit breaker, in right, has been a region not well covered by either. The disconnecting switch, simple and inexpensive, cannot interrupt load currents, much less faults. The breaker can do the job, but is expensive for many applications where its high interrupting capacity is not needed. Fused disconnecting switches do not fill the bill because of the manual attention that must be given fuses after their operation, and because the interrupting capacity of these devices makes them inadequate for load-current switching.

The solution to the problem comes by way of an entirely new type of circuit interrupter. This consists of an axial-flow interrupter of the general type used in compressed-air interrupters, but—and this is the important new feature—surrounded by sulfur-hexafluoride gas. The whole is contained in a porcelain housing, permanently sealed to maintain the gas under about two atmospheres' pressure, and mounted on a standard, outdoor air switch. The dielectric strength of sulfur hexafluoride at 30 pounds' pressure is comparable to that of insulating oil. This permits the interrupter to be light in weight, small in dimensions, yet have good current-interrupting ability. Switches with the new interrupters are available for circuits between 7.5 and 115 kv, and with interrupting capacity of 600 amperes to make them suitable for interruption of transformer magnetizing currents, line charging currents, and load currents. They require no renewal of dielectric because none of the sulfur hexafluoride is consumed in the arc-interruption process.

Relaying and Communication

This overload relay follows either inverse or very inverse curves.



At left, a new thermal relay element (BL-1), without case.

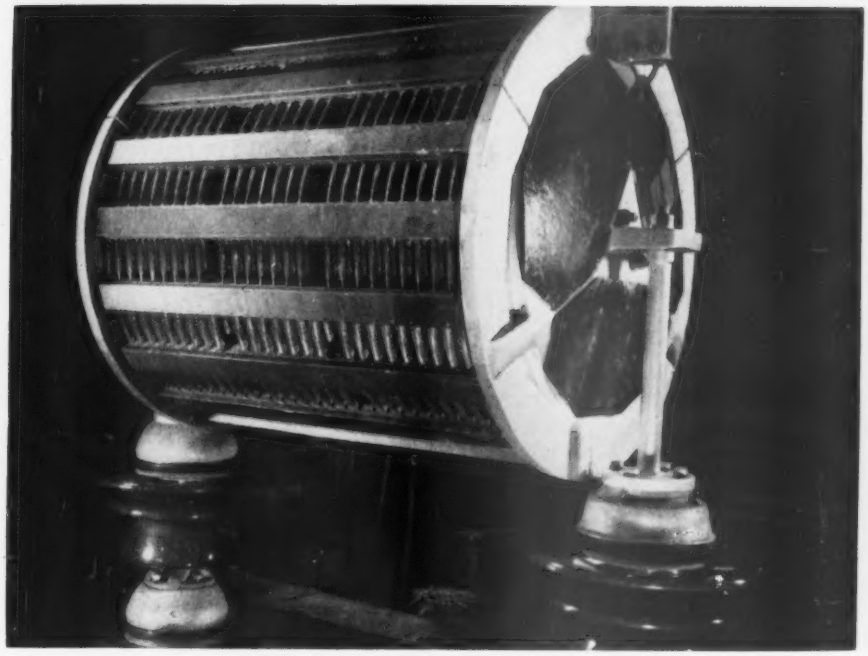
More Versatile Relays

A TREND in relays is to increase the capabilities of a given relay, if possible, to make one do the work of two. To the relay (RC) used for automatic reclosing of circuit breakers a set of contacts has been added that provides means for locking out the instantaneous-trip elements of the protective relays after the initial opening until the reclosing cycle is completed. Previously this work was done with separate auxiliary relays. Also the relay can be connected to utilize preclosed contacts for the first one of the multiple reclosures, so that for fast reclosing of breakers the relay itself does not contribute any time delay.

The thermal time-delay relay (BL) used for protection of medium and large motors has been improved so that it gives faster response on extreme overloads. Previously, the relay was often supplemented with a long-time overload relay of, say, the CO type, to give adequate protection on severe overloads. In many such cases this will no longer be necessary. The improved relay (B-L1) characteristic is obtained by removing all insulation other than air between the heater and bimetal spring. This makes the bimetal additionally sensitive to both radiant and conducted heat on extremely heavy motor currents.

Polarization of directional overcurrent ground relays has usually been accomplished by utilizing residual voltage or current. Two relays were available, one for voltage polarization (HCR) and one for current polarization (HCRC). The new type HCRD can be polarized by voltage and/or current. A power company can stock a single relay as a spare.

The new CO relay, introduced early last year, brings to the protective-relay field remarkable new operating benefits in overcurrent relaying. The new CO provides a higher degree of flexibility, greater accuracy, and greater reliability than its predecessor, which on its own merits has established a commendable record. Until the advent of the new CO relay separate relays were required to provide the so-called inverse or very-inverse time versus current characteristics. This CO



With load and fault currents increasing, line traps, used to block power-line carrier currents from entering certain line sections, must have greater capacity. This new one has a rating of 1200 amperes (800-ampere traps have been the largest). The copper cables, instead of being wound on a porcelain tube, are gripped in bars cast of high-strength mica-filled plastic. This gives better cooling and permits tap connections for tuning to be made inside the unit.

relay provides a single element that can be calibrated to either of these two characteristics or an intermediate characteristic.

Four separate and independent adjustments provide means of calibrating the new CO relay to correspond to the published or other desired characteristic within accuracy limits previously unattainable. Once calibrated the characteristic is permanent. This reliability is insured by a cast Alnico damping magnet. Other features include a gearless design, metal-to-metal contact in all electrical connections, even including the tap-changing assembly, and a one-piece die-cast frame.

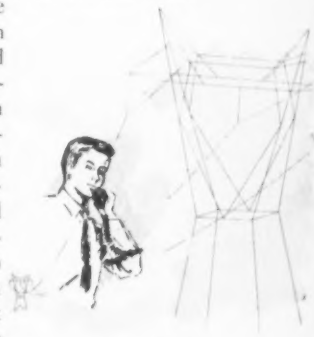
Improved Power-Line Carrier

A YEAR AGO the first stage of a program to develop the most modern power-line carrier system possible was completed with the announcement of three major components of the system (identified as type FD): frequency-shift apparatus, tone equipment, and line-coupling tuners. Since then the program has been rounded out by the addition of relaying and voice-communications equipment.

The *relaying equipment* is distinguished by several qualities. It can operate over lines having a 40-decibel noise attenuation under normal levels, which is 5 to 10 decibels noisier than has been possible before. This means the equipment can be used on longer lines or under heavier sleet, which increase the losses. The equipment makes maximum use of the frequency spectrum inasmuch as it can be supplied without the spectrum-consuming emergency communications channel usually provided with relaying equipment. This is in keeping with the philosophy that modern communications circuits are so reliable it is a needless waste of channel space to provide an emergency voice channel of low quality for infrequent use. The equipment also has a directly calibrated attenuation test unit so that the margin of safety under any line or weather conditions can be read directly.

The new *communications equipment* operates directly from a station battery. This gives assurance that the system is available when it is most needed—i.e., when the a-c system is experiencing trouble. The equipment is provided with filters in input circuits to reduce noise from telephone and supply lines. Receiver output filters are also available to ensure transmission with low distortion. Like the relaying equipment—and for that matter the other elements of the FD group—the communication apparatus is much smaller than the equipment it supersedes. Many more functions can be obtained in a given amount of cabinet space. All units include heater-current regulation for longer tube life.

Carrier and Iron Ore—A power-line carrier system for a job quite different from the usual power-transmission-system applications is being developed. This is to provide voice and teletype communication from the St. Lawrence River to Knob Lake in Labrador, where the much-discussed iron deposit is to be developed. The carrier will operate over a wire circuit on the 13-kv power-transmission line paralleling the 360-mile-long Quebec, North Shore, and Labrador Railway. The carrier, operating on the single-sideband principle, will provide eleven voice channels and four teletype circuits between three terminals—at Seven Islands, which is the river terminus of the railroad, at Midway, and at Knob Lake. Power-line carrier was chosen in preference to a microwave system which would have required numerous repeater stations. In the severe winter weather of the region these microwave repeaters would have been difficult to maintain.



The Newest in the Newest of Communication Techniques

COMMUNICATION engineers several centuries ago conversed rather well between distant visible points by smoke signals. Hilltop-to-hilltop communication went out of style for quite awhile. But, it is back again. In an electronic form—and without smoke, the engineers hope. This modern version is called microwave. It is the relaying of signals between visible points averaging, say, 30 miles distance apart.

Born of radar techniques, microwave communication is al-

ready established as a transcontinental television channel and for commercial telephone functions. Now it is fast becoming a medium for signals of many sorts by electric-power utilities and pipeline companies. Still in its infancy—it's about four years old—new developments are showing up fast. Last summer a vastly improved microwave system emerged from the Westinghouse shops. It operates at 2000 megacycles, which permits it an enormous traffic-handling ability—say, 30 separate, simultaneous telephone conversations, or up to 450 teletype channels. This is many more than the 960-mc band previously exploited. Also the system is much less subject to fading than the highest of the three channels (6700 mc) available for private microwave use. Fading would be a nuisance, but in this 2000-mc equipment it is overcome by giving the receiver an extra margin of sensitivity of 30 decibels (i.e., 1000 to 1).

The new system uses the frequency-division method of combining the many voice and other types of information into a single signal for transmission over the microwave circuit, to be properly sorted out again at their destinations. Another method of multiplexing, as it is called, is by time division, in which samples of all the signals are transmitted in succession rapidly enough for coherence at the receiving points. With this method, if certain common circuits fail, all communication is disabled.

In frequency division, each signal—be it voice, telegraph, telemetering, relaying, facsimile, or any other—is assigned one sub-frequency as its special carrier. Then these individually modulated sub-carriers are bundled up for transmission over the microwave carrier. By filtering, it is easy to unscramble the sub-carriers at the receiver points for individual demodulation into faithful replicas of the original information. Loss of one sub-carrier channel has no effect on the other information channels.

The new microwave equipment possesses several important technical features. One has to do with party-line operation of voice channels. Instead of engaging in the complexity entailed by using the single-sideband method of providing party-line circuits, a technique known as "squirt modulation" has been devised. With this system the amplitude of the sub-carrier for a given channel is controlled by the voice signal at the transmitting station. When no signal is entering the microphone, the sub-carrier is cut off and hence the condition for creating the interfering whistle is avoided.

Distribution

The number of voltage-change steps in the pole-mounted regulator has been increased from 8 to 16, with double the operating range. This has been accomplished by an alteration of the tap-changer mechanism. With these 16 steps the distribution voltage can be held to within one volt of the 120-volt standard. This regulation, which is the closest required by industry, is obtained with the least-frequent switch operations and least maintenance.

News from the Distribution-Transformer Camp

UNTIL now *three-phase, pole-type transformers* have not figured much in the power-distribution picture. But they soon will. The rapidly mounting domestic three-phase loads, particularly air conditioning, will see to that.

The promised greater demand for three-phase distribution transformers has led engineers to design a wholly new unit, in both the conventional and the completely self-protecting types. These take advantage of the fact that larger demands justify a design suited to quantity production methods and tools. The results include numerous benefits in performance and ease of manufacture of the units. The most important change is in the core material. It is now feasible to design and provide facilities for using wound-type cores of Hipersil

Enclosed Distribution Transformers

For many indoor applications transformers with oil insulation are not looked upon favorably. For some places, such as textile mills where lint abounds, the open, dry-type isn't welcome either. Now comes a perfectly safe transformer (type E). It is completely enclosed; is non-ventilated. The use of class H insulation makes it possible to operate the transformer at higher temperatures than with classs B insulation. It is thus able to meet the underwriters' requirements that it not burst into flame when the unit finally fails due to excessive temperature. The units up to 10 kva in size are no larger or heavier than comparable open-tank transformers with class B insulation.

grain-oriented steel instead of hot-rolled silicon-steel punchings. Curiously, for a three-phase transformer this presents problems. The trick is to devise a three-leg arrangement of the core, using the steel so that the direction of the flux is the same as the grain and is balanced in the three legs (and, of course, is an arrangement that is practical to make). 'Tain't easy. Try to figure it out sometime.

Several ways to build a three-phase wound core are known, but in none of them is the flux completely balanced. However, one way has been found that gives satisfactory flux conditions and has the necessary factory simplicity. It consists of one wound core, like the familiar type C, to one side of which is butted one half of a similar core. Conventional banding procedures for both the main and side core hold the complete assembly together in a single rigid structure. This design has the great merit that, when assembled with the prewound coils, the assembly fits well, with little waste space, into standard round tanks.

The new three-phase units are much smaller and lighter than their predecessors. This results from the use of Hipersil cores and from the inclusion of many weight-saving features developed for the large-volume, single-phase units. In each of four ratings—15, 30, 45, and 75 kva—tank diameters have been reduced by one or two sizes (the 45 kva occupies a 20-inch instead of a 24-inch tank, for example). Oil reduction averages 28 percent. Total weight is, on the average, 21 percent less. In general, the new units have considerably more coil surface exposed to oil circulation. Thermal gradients are therefore less, resulting in better performance.

The requirement for *circuit breakers* for inclusion in distribution transformers is for greater and greater current-interrupting capacity per cubic inch of space occupied. And in the smaller transformers—say 15 kva and less—the cubic inches allowed aren't many. A few years ago a small but powerful breaker was developed for distribution transformers. Known as the BR, it has an interrupting capacity of 10 000 amperes at 240 volts and is used in the single-phase transformers of 37.5 to 100 kva, for three-phase units of 9 to 150 kva, and for banking units (CSPB) of 25 to 37.5 kva, single-phase, and 30 to 75 kva, three-phase.

Space is scarce in the smaller units—particularly that in the new three-phase CSP transformers up to 45 kva. Also these smaller units do not require such high interrupting abilities. For these reasons an extremely compact breaker (LR) has been created. Where possible, features of the BR were borrowed, but many of the features of the LR breaker are entirely new. It can interrupt 5000 amperes at 240 volts, yet a unit pole is contained in less space than in a cigar box. The interrupting capacity is 24 kva per cubic inch. The breaker it replaces could manage but 17.

The new breaker has been designed also to operate at lower contact temperature. This is achieved by using lower resistance flexible cables, heavier contact pressure, better self-aligning action, free oil circulation around the contacts, and new contact material.

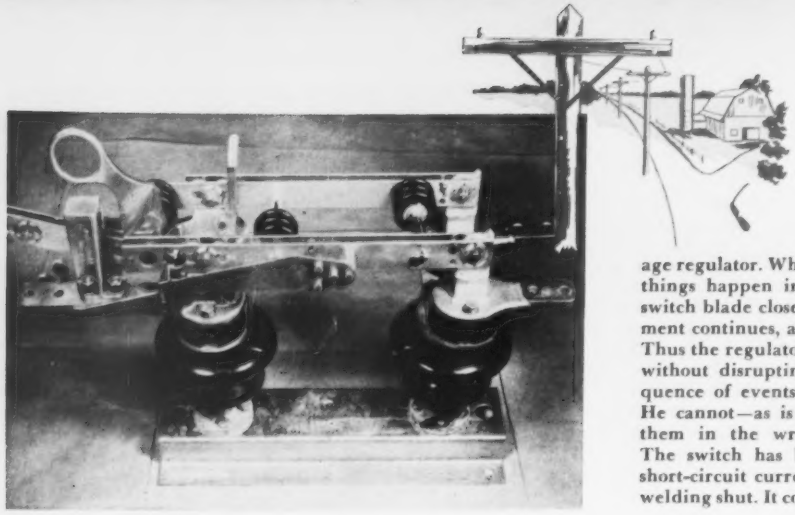
Comparison of old and new three-phase distribution transformers.

Distribution-transformer coils are machine wound, many at a time.

Distribution-Transformer Coils Wound in Multiple by Machine

DESIGNERS of distribution transformers have taken a leaf from the book of radio manufacturers. This is machine winding of several transformer coils simultaneously. Radio men call this stick winding. A long insulating tube is rotated in a lathe. As it turns, from two to a dozen coils are wound, from separate spools of wire, with a short space between each coil. Then the "stick" is simply sawed apart into the individual windings.

This process, which had its beginning in small distribution-transformer manufacture soon after the war, has many benefits. The quality of the transformer, by comparison with manual winding, is improved by virtue of the controlled tension and by getting better lay of the wire. In addition, the technique has made it possible to produce many more units from available space and facilities. This has been of great value to the industry during the recent years when the demand far exceeded the ability to produce them.



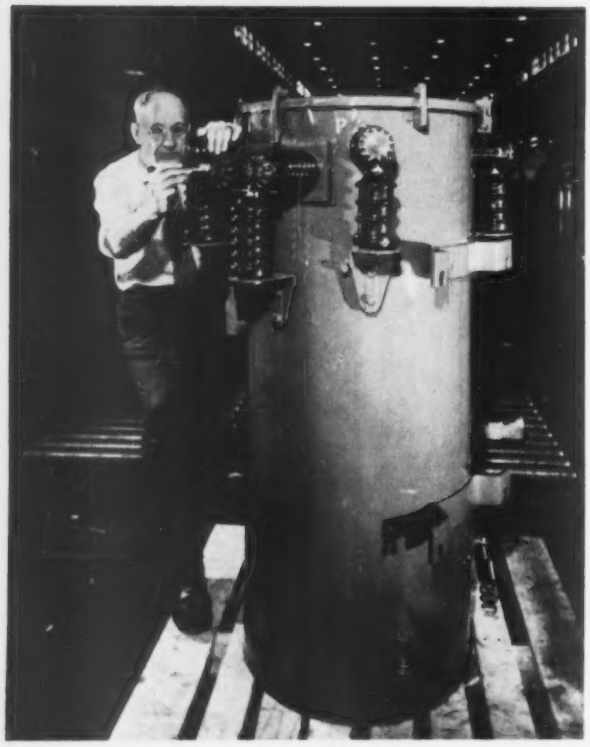
Regulator By-Pass Switch

A new regulator switch does the work of three. It is associated with a voltage regulator on a distribution circuit, and is operated when it is desired to isolate or reinsert a voltage regulator. When the lineman with hook stick opens the switch, things happen in the following sequence. A small, light-duty switch blade closes to by-pass the voltage regulator. As the movement continues, a switch on each side of the regulator is opened. Thus the regulator is de-energized for inspection or maintenance without disrupting service. Closing the switch reverses the sequence of events. Thus the lineman has but one thing to do. He cannot—as is possible when three switches are used—open them in the wrong sequence to cause service interruption. The switch has been tested in the high-power laboratory at short-circuit currents up to 40 000 amperes without the contacts welding shut. It comes in three voltage ratings: 7½, 15, and 23 kv.

Capacitor Banking Made Easier

ONCE upon a time, installation of a distribution capacitor (on 2400-volt to 13.8-kv lines) necessitated buying the separate capacitors and three separate four-unit racks—then the whole thing was bundled up and mounted on crossarms. Furthermore, switches were extra, and had to be mounted separately. Everything but the mounting has been eliminated by the Autotrol—a compact, factory-built, 12-unit assembly, complete with three single-phase oil switches ready to mount. A plug-in type control about the size of a watthour meter, which can be pole-mounted, determines the switching of the capacitor. The control can be supplied to operate from either line voltage or current. These control units can be calibrated and set at the factory.

New streetlight regulator for operation on the cascading scheme.



Standardization of Network Transformers

SINCE the low-voltage network system was sponsored by Westinghouse in 1922, network transformers have been designed to suit each system. The differences, while not fundamental (they apply mostly to arrangement of auxiliaries, fittings, and to ratings) absorb a great amount of engineering time and retard factory assembly. Committees of EEI and NEMA have been hard at work to end all these by the establishment of industry standards. Their proposals, now formulated, are being reviewed by power companies, manufacturers, and engineering societies. These standards, if adopted, will provide for four sizes—300, 500, 750, and 1000 kva—and for high-voltage ratings up to 27 060 volts.

Modern Lamplighter

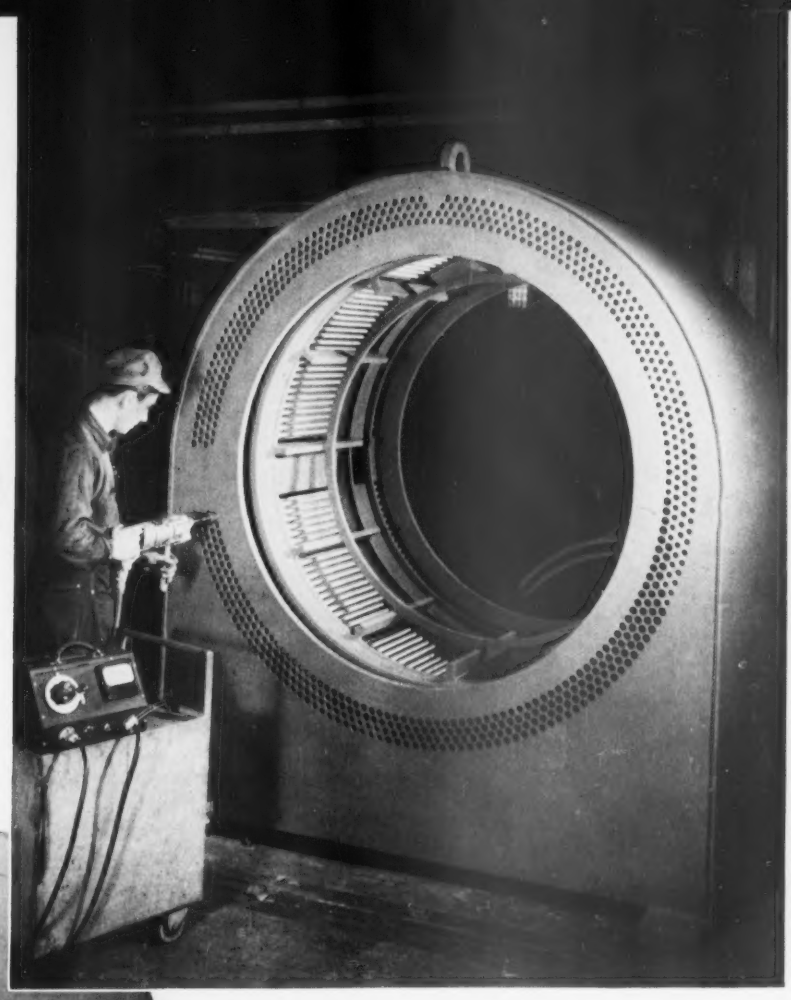
IN "merrie olde England" at nightfall a lamplighter went about lighting the feeble gas flames that provided faint glows of light along the city streets. Picturesque custom! Or so it seems from this distance.

The lamplighter has long since gone. But the problem of turning on the streetlights each evening in a big city remains. It can be done in many ways, some pretty fancy—like high-frequency carrier current, or photoelectric cells. Some do it by time clocks, and some even manually. None come cheap. A new type of control built into the constant-current regulator offers possibility of giving a better answer.

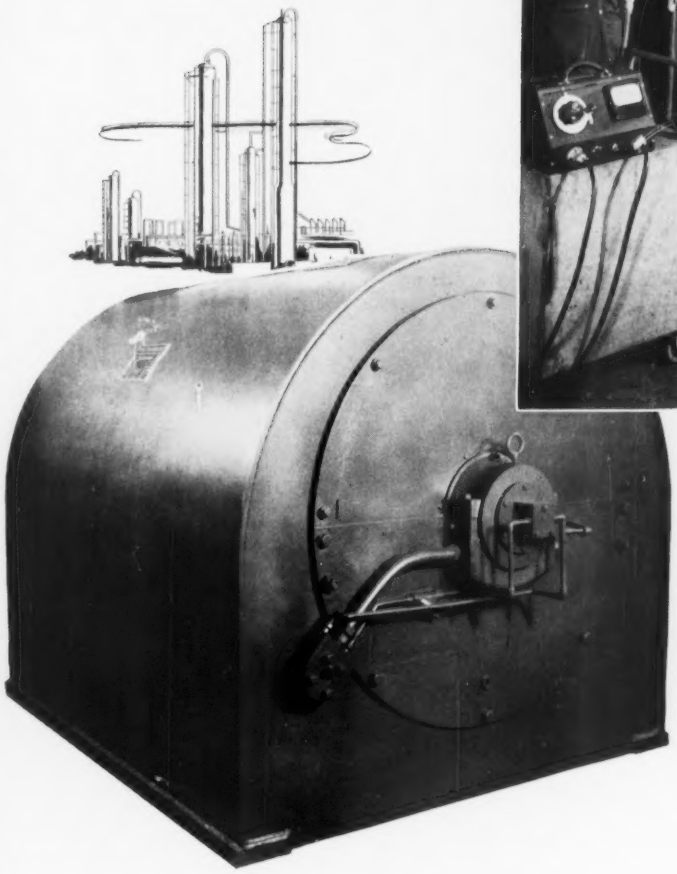
Westinghouse engineers, working in cooperation with those of the South Bend Controller Company, have devised an ingenious relay that is made a part of the regulator. With this system, the only human act required to turn on the city's lamps is for an operator at a central point to close a switch. This energizes the nearest regulator, resulting in lighting of the lamps on its "beat." This action, via the relay, energizes the next regulator, and so on, chain or cascade fashion, throughout the city. The cascade idea is not wholly new, but the incorporation of equipment for accomplishing it as a part of the current-regulator package is, and should hasten the adoption of the scheme.

A 300-kva power center with an overall height of 36 inches has been developed for use in mines. The unit is basically a dry-type, air-cooled transformer with related circuit-breaker equipment designed to be a neat, compact, portable unit for use underground. Four-conductor, plug-type receptacles provide connections for the high-voltage (4160/2400-volt) and the outgoing low-voltage (480/240-volt) circuits.

Right, a workman is rolling tubes into place for an enclosed tube-type motor. Below is a totally enclosed, self-cooled motor, used in refineries and other hazardous locations.



Motors



Significant Developments in Large Induction Motors

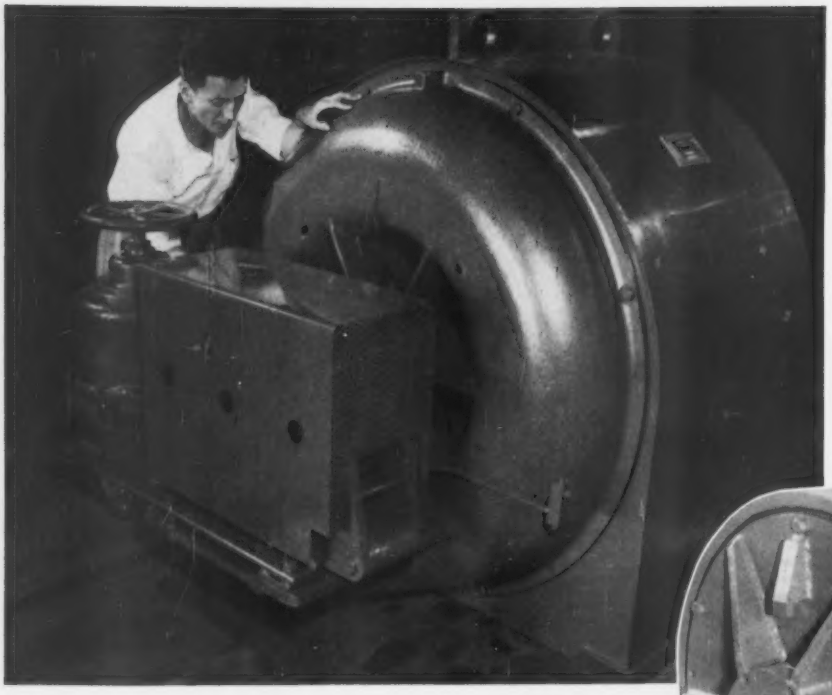
A NEW MOTOR resembles a small steam condenser with its nest of many closely spaced tubes more than it does a motor. It is the tube-type construction for totally enclosed motors, which is increasing in popularity. This is particularly true in the larger sizes—up to 2000 hp—for such jobs as drives for power-house boiler-feed pumps, pipelines, refineries, and chemical plants.

Two methods are used successfully to help a big, totally enclosed, self-cooled motor get rid of its heat. One, introduced by Westinghouse about seven years ago, is to intersperse fins of copper through the magnetic laminations of the stator. The excellent thermal conductivity of these fins enables them to carry heat out of the core rapidly. This solution works well, but introduces the possibility of gathering dirt where the fins project from the core.

The second method is to surround the motor stator with a nest of tubes parallel to the motor axis. Hot air developed in the motor is circulated around the outside of the tubes by an internal blower. Meanwhile outside cooling air is driven through the tubes. The result is an efficiently cooled, totally enclosed motor, suitable for dirty and explosive atmospheres. The motor can be made explosion resisting, and is expected to meet the tests for classification as explosionproof.

Several tube-type motors were built by Westinghouse in 1936. But these were relatively costly as the tubes were fastened to the tube sheet by welding. The new method is to roll the tube ends into the end plate as is common practice with steam condensers. This reduces cost.

The Weather-Protected Motor—Both the fin-type and the tube-type induction motors are, obviously, more expensive than the open-type. For some jobs, such as in outdoor power plants, a motor of lower cost, which can be used outdoors, is highly desirable. A new weather-protected motor fulfills this requirement. It is an open motor but has covers that protect it from normal falls of rain and snow. Water or snow can enter only horizontally. The openings are arranged so that water driven by high winds is swept right on through. Baffles prevent water from reaching the windings. These motors also employ the new synthetic-resin insulation (see story on next page), which possesses moisture resistance several times bet-

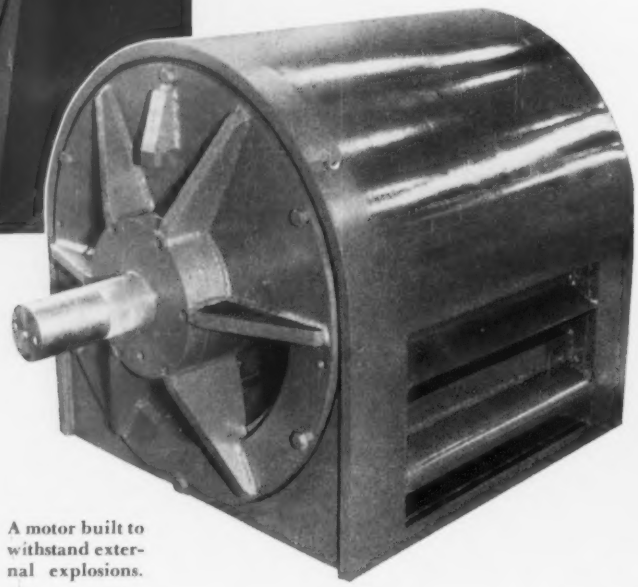


2000-Hp Induction Motors

Even one 2000-hp, squirrel-cage motor is rare. This makes more spectacular the construction of over 500 "carbon copies" of a machine of such exceptional size. These are six-pole machines for a single application. Because they run fully loaded continuously, a high order of efficiency is worthwhile. The designers have been able to meet an efficiency of 96 percent or better, which is a full percent higher than standard. The rotor bars are fastened to the end rings by induction brazing, no mean accomplishment with rings 30 inches in diameter, considering the thermal expansion that occurs during brazing.

ter than the conventional asphalt-base tape impregnants.

Two-Pole Induction Motors are more and more common in the large sizes—up to about 3000 hp. This is largely because of the growing sizes of boiler-feed pumps and pipeline compressors. This family of open motors, furthermore, has recently been importantly improved Use of direct-connected pumps improve the oil system. The enclosure of oil piping within the sump tank streamlines the appearance. Spherical seats on the bearings make them self-aligning and insure the large contact between bearing shell and motor housing necessary for good heat flow. Air from the high-pressure side of the blower is introduced into the bearing seals so that oil leakage will be into the bearing, not out of it.



A motor built to withstand external explosions.

A High-Torque, Shock-Resisting Motor

A 150-HP, squirrel-cage motor for use in a Colorado mine was posed with two unusual requirements. It must withstand the shocks from blasting 20 feet away. Also, it must develop 400 percent rated torque on starting.

Indicative of the force of the blasting, it was found that nameplates mounted in the usual manner were popped off by the blast force and resulting vacuum. This minor problem was met by venting the area covered by the nameplate to equalize the pressure on both sides.

To give the motor itself adequate strength, the outside shell is made of steel plate one inch thick. The heavy steel reenforcing pieces add to strength. The end bells are not "bells" at all, but flat steel plates with a heavy steel bearing housing supported and braced with steel ribs.

To minimize projections, the inner bearing caps are fastened with countersunk cap screws. Instead of the standard conduit box, the leads are brought out through a ventilation opening near the feet. A special clamp holds the conduit and the motor leads in place regardless of blasting forces.

The high slip—five to eight percent—necessary to provide high starting torque was obtained by making the rotor bars and rings of high-resistance alloy and by using a special high-torque winding in the stator.

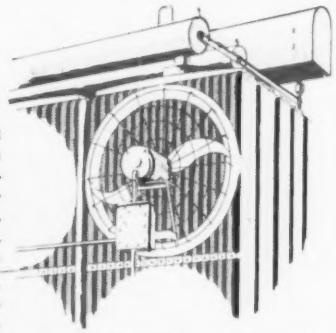
Better Insulation for Low-Voltage Machines

THERMALASTIC insulation has a new running mate. Thermalastic insulation was developed initially for the long coils of high-voltage generators. Its electrical qualities are so much better that similar insulation has been sought for low-voltage machines. Research and materials engineers have met this request with a modification of the original high-voltage Thermalastic insulation, but custom built for the somewhat different problems posed by large motors and generators of 6600 volts, and down to about 1000 volts. Here tape separation, which sometimes results with asphalt-type insulation after many temperature cycles, is less likely because the coils are much shorter. On the other hand, resistance to moisture and corrosive atmospheres and good dielectric strength are of particular importance for many motor applications.

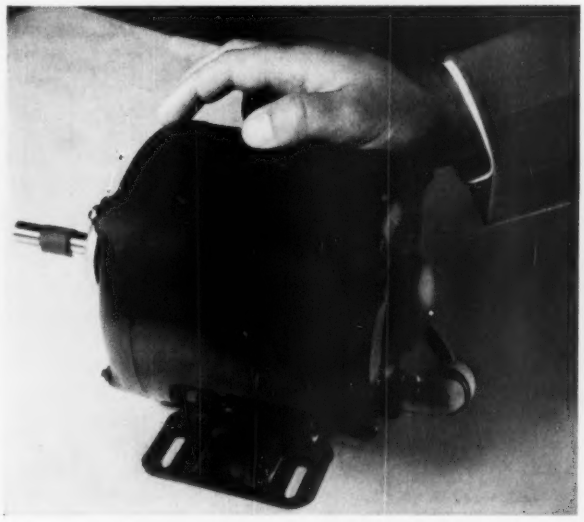
The new low-voltage insulation is based on a synthetic resin compounded and applied somewhat differently than

high-voltage Thermalastic and is much more quickly cured. Advantages by comparison with present conventional insulations include greater mechanical strength, better heat-transfer qualities, superior dielectric strength, and exceptional resistance to moisture and other contaminants.

Single-Phase, Three-Phase Motor



This motor is as much "at home" on single phase as on three phase. It has a Scott-T connection, long familiar to transformer men but believed to be new in rotating equipment. The motor uses concentric windings, which can be placed by machine, instead of a progressive winding. Except for starting torque, the motor provides equivalent performance on the two power supplies. The motor is used, for example, to drive fans for cooling outdoor power transformers, and makes it possible to use a single motor interchangeably for either type of power supply. For this application, built-in Thermoguards protect the motor if fan blades become blocked by ice.



Better Motors Made Faster

SOME PRODUCTS are improved, not by any change in design, but by better manufacturing methods. Such has recently been the case with general-purpose fractional-horsepower a-c motors. For example, in the two new Westinghouse plants built for the manufacture of these motors (at Union City, Indiana, and Bellefontaine, Ohio) several advanced production techniques have been introduced.

The cage windings in the rotors of these motors are now die cast of aluminum—and four at a time. Those for previous rotors of this size were made of copper. Die casting provides much greater uniformity, an electrical efficiency that runs one or two points better, and a considerably better and more consistent speed-torque curve.

The die-casting machine was developed especially for accurate casting on a high-production basis. It is built so that slight variations in length of the four stacks of punchings are compensated with the result that all four are cast alike. An automatic, mechanical unloader eliminates the disagreeable chore of handling the heavy casting as it emerges, hot, from the machine. A silicone die lubricant prevents sticking in the molds, and makes it unnecessary for a workman to stand by to pry out a reluctant casting. With this die-casting machine, 300 rotors are cast hourly—one every 12 seconds.

Rotor and stator lamination punchings for industrial fractional motors have been punched out on a machine that slides the square blanks down a 40-degree incline into the reciprocating "cookie" cutter. The completed punchings are carried away by gravity. Such a system makes 80 rotor and 80 stator punchings per minute.

This process has been considerably speeded up—to 135 strokes per minute, i.e., better than two per second—by an entirely new machine and feeding device. The blanks are simply stacked by hand on a vertical indexing feeder, are picked off with magnets, placed in position, stamped, and then hustled out of the way of the next by a powered device.

These motors have two windings, one for starting, one for running. It has long been practice to place the running winding in the stators of fractional-horsepower motors by machines. The starting winding, however, has been inserted by hand. Now machines have taken over this job too—with, believe it or not, an assist from the first winding. After the running winding is in place, it is energized with 12 volts, direct current, thereby making magnets of the poles in the core. These poles then assist in holding the forms in position for the automatic insertion of the starting winding.

Rotors for small motors are precision die cast, four at a time.

Drives and Controls

Packaged Power Supplies on the Increase

THE INCENTIVES to package process-line power supplies and their controls are growing steadily. Saving of installation expense is perhaps uppermost; closely followed by greater compactness, fewer elements, and the benefits of factory coordination, assembly, and testing.

Numerous examples of new applications of packaged drives are at hand. A typical one is for a brass-rolling mill. This includes a motor-generator set to furnish power to a 50-hp mill motor and a 10-hp reel motor. A magnetic amplifier takes the place of a rotating regulator, thereby reducing by one the number of rotating machines. Motor-generator set, magnetic-amplifier regulator, and all switching are contained in a single cabinet of modest size.

A somewhat similar packaged control and power supply has been put together for a machine to make heavy, asphalt-type roofing paper. This machine—a simplified version of the paper-making machine—is driven by ten motors, all supplied by a single generator. The m-g set, all contactors, and protective devices are contained in one cabinet. No regulator is necessary for this application.

Progress in Basic Control Elements

WHILE THE horsepowers and speeds of rolling mills and other processing lines are increasing, the *master switch* to control them is becoming smaller. The new master switch (type DM) occupies 35 square inches of desk area; the old one 87 square inches. Most of the reduction comes by making the cam shaft vertical. In the old switch the cams are mounted on a horizontal shaft. Hence it occupied considerable desk-top area. There is ample space vertically under the desk. The cam shaft has been turned on end and connected to the handle by a small right-angle gear. Handle motion remains the same. The cams are of molded phenolic, but are smaller in diameter than the Micarta discs used before. Instead of mounting the switch in a rather heavy grey-iron sand-cast housing, an aluminum die-cast case is used. This makes for better appearance and less machining. Extra-length wiring is used, so that the whole switch can be lifted vertically from its well in the desk for access to the cams and contacts.

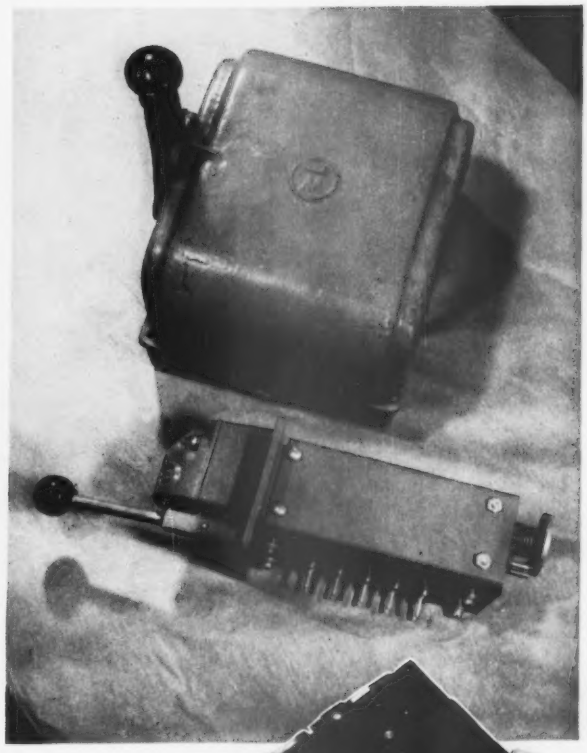
This self-contained, regulated power supply for a textile slasher drive uses a magnetic-amplifier, selenium-rectifier excitation system.

A user of *general-purpose a-c motor starters* can now purchase a standard starter and adapt it easily to his special needs. The new panel contains all the basic elements—contactors, relays, and overloads—but space is provided for later additions of other devices, such as control transformer, interlocks, fuses, and another auxiliary relay or timing relay. The previous starter panel had no space for these additional modification items. The extra panel space comes, in part, from a slight increase in panel size, but mostly because the control elements introduced in the last year or two are smaller than their predecessors. The starter also employs the new polyvinyl-insulated wire.

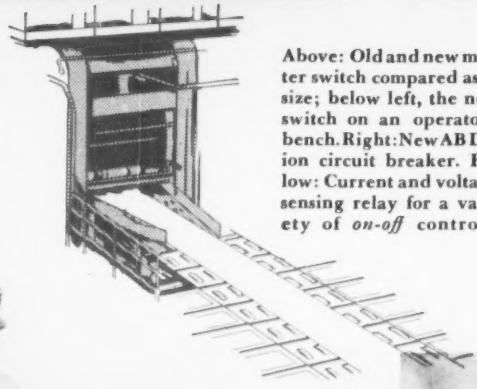
The *current-and-voltage-sensing relay* (AV) used for many purposes, such as for *on-off* control of machine fields, to operate on loss of machine field, or excessive rate of acceleration or deceleration, has been redesigned to obtain a greatly multiplied range. Knife edges greatly increase bearing life.

Explosionproof Enclosures—In designing enclosures for distribution and control devices used in hazardous atmospheres, the engineers got a break. They have customarily used high-strength grey cast iron with a tensile strength of approximately twice that of ordinary grey cast iron, because these enclosures must be able to withstand severe internal explosions. Even with high-strength iron, wall sections must be fairly thick, resulting in heavy, cumbersome enclosures. The materials and foundry people have produced a new casting metal, which they call nodular iron. This is more ductile and has substantially greater tensile strength than high-strength grey iron. Use of nodular iron thus results in lighter weight, more compact castings. For example, the enclosure for a 225-ampere AB breaker becomes 250 pounds as compared to 435 pounds, i.e., 185 pounds less to handle and mount. It also means a substantial saving in freight charges. For example, the saving in shipping a unit from the plant at Beaver, Pa., to Kansas City, Mo., is $5.29.

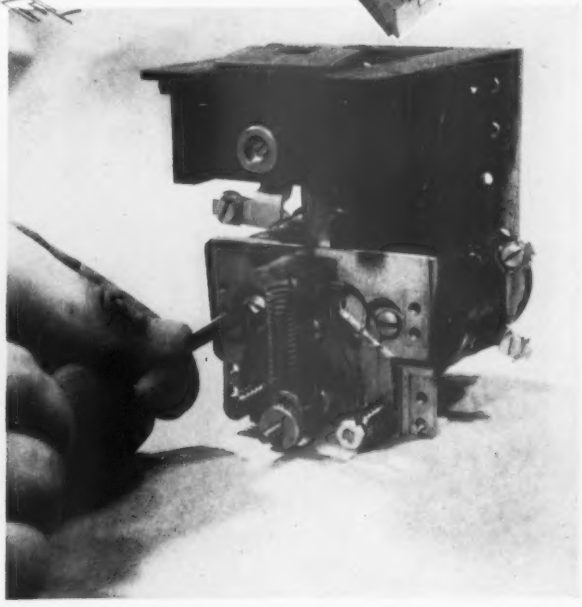
The new *motor-circuit switches* look more like circuit breakers. They are, in fact, adaptations of highly successful molded-case circuit breakers, without automatic trip elements. In addition to providing a switch, using thoroughly approved breaker parts, the length is much reduced over the nonautomatic-type circuit breakers. The 200-ampere size is 1⅜ inches shorter than the J-frame nonautomatic breaker. The 100-ampere unit is three inches shorter than the nonautomatic



The cover-operated disconnecting switch used with bus duct has been made shorter so that it does not overlap two outlets. Hence, adjacent bus duct outlets are usable.



Above: Old and new master switch compared as to size; below left, the new switch on an operator's bench. Right: New AB Deion circuit breaker. Below: Current and voltage sensing relay for a variety of *on-off* controls.



Pickup used as part of a control for constant-speed metal cutting.

F-frame breaker, and the 60-ampere size is two inches shorter than the equivalent E-frame nonautomatic breaker. These switches are soon to be applied in both the fused and unfused motor starters, advantage being taken of the smaller size switch to provide starters smaller in overall dimensions.

Relays (type N) are used in large numbers in machine tools and process applications for the coordination of operation of several motors. In an improved version of this relay, the contacts can be quickly changed from normally open to normally closed or vice versa, with the same parts. This could not be done previously. The relay is a companion to the popular type N contactors and retains the highly successful hardened knife-edge bearing, kickout spring, and easily removed coil.

A new enclosure has been developed to capitalize on this shorter length of breaker. The lighting and power panelboards for industrial plants and buildings are always crowded. The new unit saves four inches in length.

The *Quicklag breaker*, long a popular breaker for domestic and other 120- and 240-volt circuits, has been provided with plug-in type terminals. Elimination of the terminal at one end of the breaker makes it much shorter and provides easier and less costly installation.

In some factories it is desirable to "cushion" the shock in the distribution circuit caused by the inrush of current during starting of induction motors. Also it is likewise advisable to limit the starting torque to a safe value depending on the characteristics of the load and the manufacturing process. For this application, a *cushion starter* has been developed for use with a motor with two identical star-connected parallel windings. Under starting conditions one winding is connected to the line, resulting in a starting torque of about one-half normal. At fixed intervals the three sections of the other winding are successively connected to the line, resulting in subsequent increases in torque. The starter is so interlocked that the operator cannot apply full torque at any time without going through the complete starting cycle.

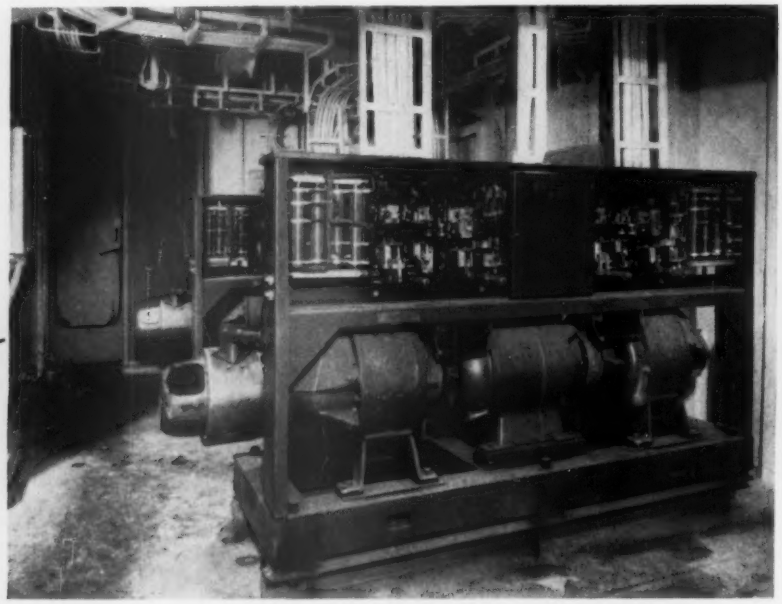
D-c general-purpose starters have been improved to the extent of providing more space for future modifications, use of polyvinyl wiring, and front wiring on size 1 and 2 starters.

A new family of individual *a-c and d-c marine starters* has been developed to provide externally operated disconnecting switches for operator safety. These conform to the major changes recently made in AIEE marine rules and to U. S. Coast Guard requirements.

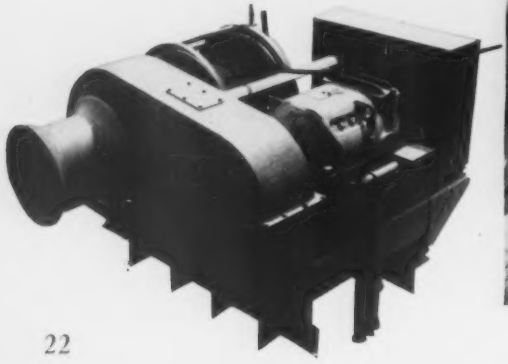
Reactor Control for Constant Cutting Speed

EACH METAL has a best machining speed. A higher speed damages the tool; a lower one cuts production. To maintain constant cutting speed when machining the face of a jet-engine disc, which is rotated and the tool is moved radially across it, clearly presents a problem. The rate of feed of the tool must obviously change as the tool moves toward or from the center. A mechanical linkage to a rheostat in the motor-field circuit has been generally used to approximate the desired speed control. But this has been clumsy.

A much better solution comes with a control employing a small reactor. A simple, small cam is cut for each size and type of part to be machined. A probe from the reactor, which is contained in a box about four inches cube, rides on this cam as the cutting progresses. As the probe moves up or down—a total distance of only a half inch—it moves an armature that



This a-c, adjustable-voltage cargo hoist, installed on the *S. S. Keystone Mariner*, combines high light-hook speed with precise control of heavy loads—in both directions.



changes the reluctance of the magnetic circuit in the reactor. Through an electronic exciter this varies the motor field strength to change the d-c motor speed to maintain the cutting speed constant.

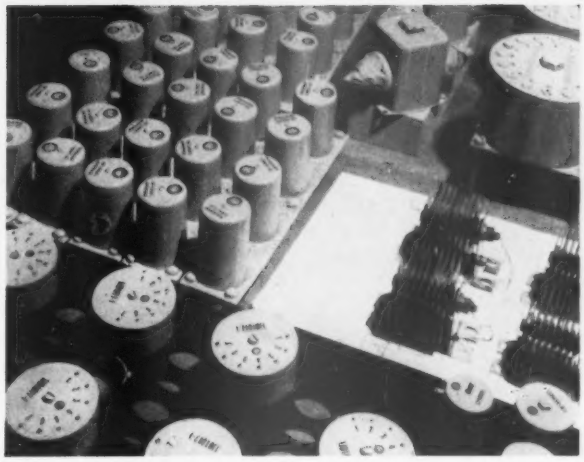
The motor has an eight-to-one speed range, obtained solely by control of motor field strength. This speed range is double the amount ordinarily available by field control. It is made possible by two sets of windings on each of the four poles. These are automatically connected in different sequences to obtain net flux changes much larger than normal.

The system avoids mechanical linkages, is stepless, and involves no sliding contacts or rotating bearings.

Marine Cargo Hoist Gets a Land Job

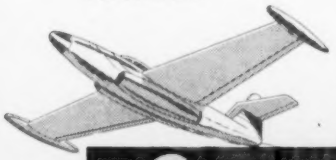
IN THE fall of 1950, a high-performance type of a-c powered adjustable-voltage control system was announced as developed especially for cargo hoists. For ship use, fast "light-hook" speeds are needed to cut down loading and unloading time. Also precise control of heavy loads is required.

This ultimate in adjustable-voltage control for cargo hoists has already found land application with but minor modifications. For example, the system is being applied to the drives of the two 165-ton powerhouse cranes of Chief Joseph Dam, in Washington. With this crane-hoist control, rated load can be lifted or lowered from standstill by as little as one-sixteenth inch. On the other hand, the empty hook can be moved at twice the speed usual for such a-c powered cranes. In other words, the full height of 80 feet can be traversed by the empty hook in five minutes instead of ten.



Magnetic amplifiers and rectifiers are in high-volume production.

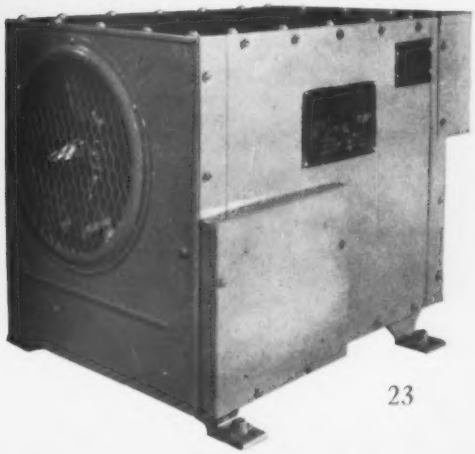
New Applications for Selenium Rectifiers



ON MANY airplanes power is generated at 400 cycles alternating current. Considerable quantities of d-c power also are required. Selenium-rectifier units effect the exchange. These units are remarkable, particularly for their light weight. For a continuous output of 200 amperes at 28 volts (5.6 kw) the unit weighs but 72 pounds. This includes a three-phase transformer, a saturable reactor, and a carbon-pile regulator to maintain constant voltage. At normal input voltage the output voltage is constant to 200 percent load.

New applications for power selenium rectifiers are of wide variety. One is to provide power for d-c motors driving air compressors for the pneumatic system, which whisks mail through tubes under the streets of New York City. Direct current is provided by four 150-kw banks and one 200-kw bank of 50-kw selenium rectifiers. The several units comprising each bank require no equalizer connections for operation in parallel. These units weigh only about one half as much as equivalent motor-generator sets, require much less maintenance, and are comparable in cost. They maintain full-load efficiency down to quarter load and the stand-by losses are but one fourth those of a comparable m-g set.

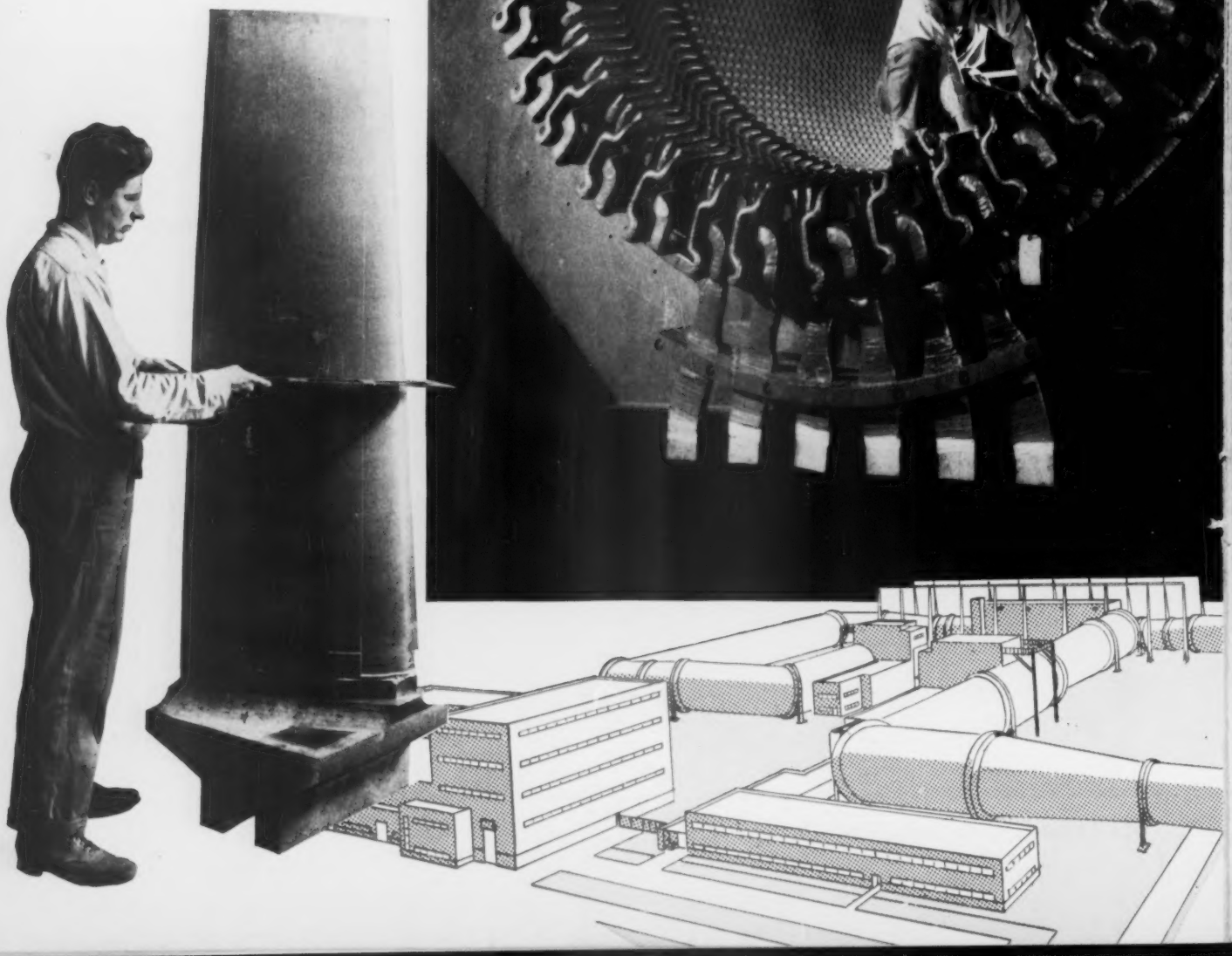
Ordinarily rectifiers are not used where the power can reverse direction. However, selenium rectifiers are being used successfully to supply d-c power to several motors driving dumb-waiters and other lifts in a new hospital. When the loads are overhauling, causing the d-c motors to regenerate, the control causes the power to bypass the rectifier and be dissipated in resistances.



Left: Selenium rectifiers used to supply air-compressor motors. Below: Light-weight selenium rectifier for aircraft service.

Wind-Tunnel Drives

A partially machined rotor blade for the transonic compressor. It is about six feet long and weighs two-thirds ton.



The World's Largest Rotating Machine

THE PYRAMIDS of Cheops, the Panama Canal, and Hoover Dam are all-time great landmarks in the history of engineering. A machine is being put together now that will rank as a classic in rotating machinery. No other rotating machine man has built comes close to it for size. It is the Gargantua of rotating machines. From end to end it will measure 575 feet. It weighs 1000 tons and its inertia amounts to the astronomical figure of 77 million pound-feet squared. The stored energy at a speed of 600 rpm is 2400 hp-hours. Four motors with a combined power of 216 000 hp are required to drive it. Two of these are synchronous motors, each being nearly one third larger in horsepower than even the 65 000-hp pump motors recently installed at Grand Coulee, which themselves were at least twice as large as any synchronous motors previously built.

This prodigious machine comprises the five compressors and drive for the transonic and supersonic wind tunnels being built at Tullahoma, Tennessee. This tunnel will be operated by the Arnold Engineering Development Center, which is under the command and supervision of the Air Research and Development Command, and is responsible for the overall United States Air Force research and development program.

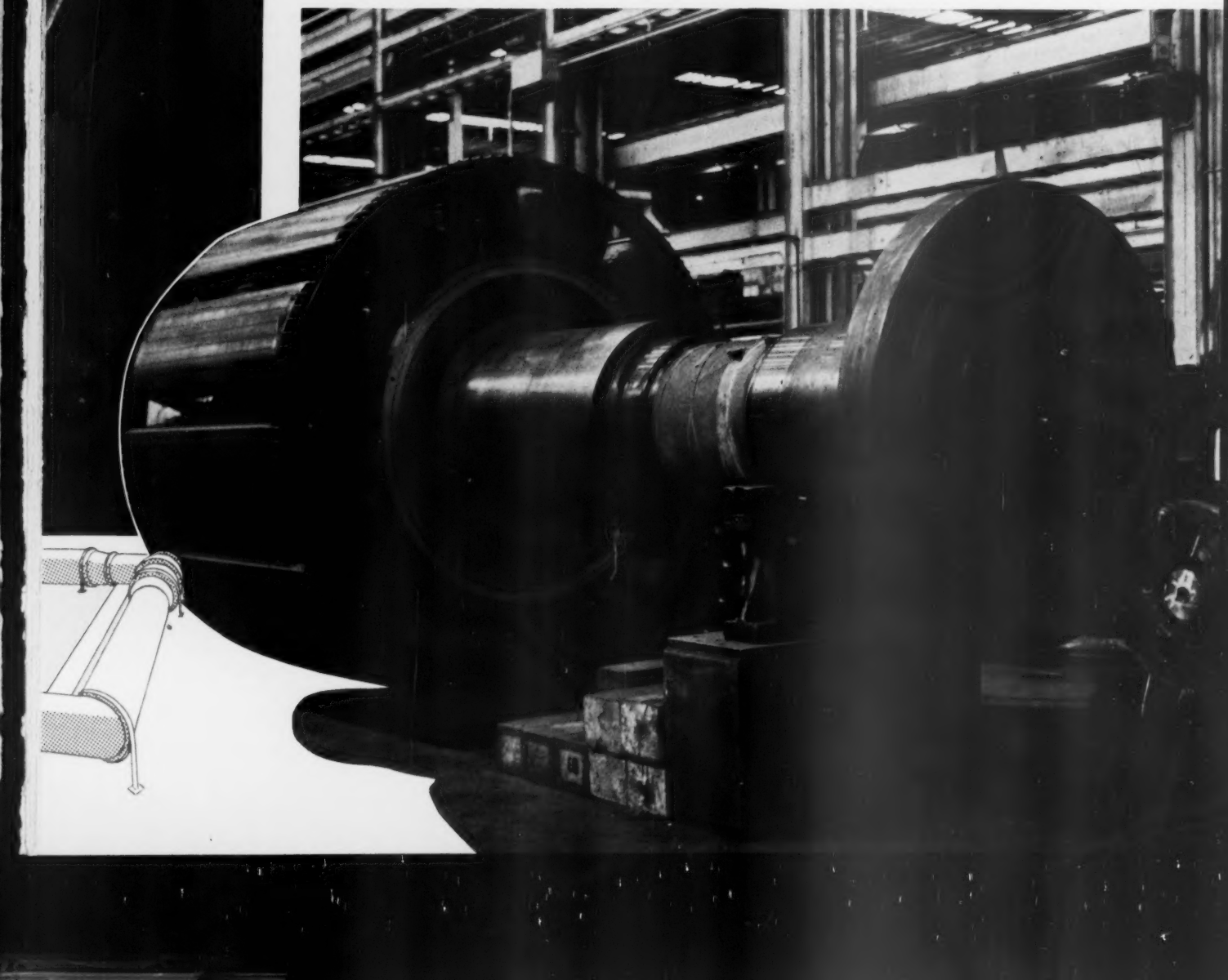
The transonic compressor will be a single unit. The supersonic compressor, however, will be four compressors in series. Statistics on the inlet-stage blades of the transonic compressor suggest the scale of this super wind maker. The blades are more than two feet across the face, six feet long, each weighing almost two thirds of a ton, and rotating at 600 rpm on a spindle 18 feet in diameter. The tip speed for this great mass is 650 mph and the centrifugal force tending to pull each blade from its roots is 800 tons.

A quarter-scale model of one of the multiple-stage compressors has been built. This model underwent exhaustive tests to insure that these outsize blades will not develop resonance at operating speed. Resistance strain gauges and an associated electronic circuit were used for observation of the vibratory characteristics of the blades under normal conditions.

The two liquid rheostats for motor speed control are also the world's largest. These will be used for secondary control of the wound-rotor machines during starting, load transfer, etc., and each is capable of a peak dissipation of about 25 000 kw. The nickel-clad steel electrodes are three feet in diameter. Although the machine represents the highest stored energy of any rotating mass ever built, it can be brought to a halt in about three minutes by using the wound-rotor motors as brakes.

The problem is not only to get energy into the air stream but also to get it out again. The air stream would become extremely hot without the large cooling system provided by Stacy Brothers. Even with 100 000 gallons of water per minute flowing through coolers the air discharge temperature is above 600 degrees F. The air in the test chamber, on the other hand, will be cold, down to about −100 degrees F.

Four motors in tandem drive the compressors. Here are the rotor and stator of one 83 000-hp synchronous motor.



Magnetic Amplifiers Go Standard

MAGNETIC amplifiers have reached that degree of maturity that makes standardization of units both possible and desirable. For the more sensitive, more exacting multi-stage magnetic amplifiers, two families of Magamps have been developed. Both are in volume production.

One uses toroidal (doughnut) cores for the first stage (or additional low-power stages if the application warrants). Toroidal or doughnut-shaped cores give best Magamp performance although they are obviously not the easiest to build. Unlike cores made of punchings, toroidal cores are continuous, and hence the windings must be threaded turn by turn through the opening. Also it is more difficult to apply insulation between turns. However, toroidal-core magnetic amplifiers in the small sizes, by comparison with stacked-punching units, give higher performance, are lighter in weight for a given power output, and have a desirably higher ratio of amplification to response time.

These standard, first-stage toroidal Magamps provide outputs in seven steps from 40 milliwatts to 440 watts and are suitable for many general applications. The cores of these Magamps are enclosed (boxed) in a housing that is vacuum impregnated with a synthetic liquid that makes the core impervious to vibration. Windings are applied around the "box," thus avoiding the variation in characteristics that result if mechanical pressure, from the windings or other causes, is applied directly to the sensitive magnetic core material.

The second-stage Magamps, applied where much higher kilowatt outputs are required, use type C wound cores of Hipersil grain-oriented steel. In fact, this family of Magamps is the beneficiary of the high order of development that many thousands of transformers have made possible. The cores are standard ones used in transformer assembly, with consequent economies, high quality, consistency, and availability. The second-stage family comprises six standard ratings between 300 and 2000 watts output. They can be used for 220 volts single phase or 440 volts three phase, and for 60 or 50 cycles. Each Magamp consists of two type C cores instead of the three-legged core, which does not lend itself to the economies of C-core manufacture.

Tubes—New Kinds, Many Improvements

Ionization Chamber—Electron tubes are sometimes called vacuum tubes. The pressures within them seldom exceed a few pounds. One of the most interesting of last year's crop could better be called a pressure tube. Its argon gas is contained at a pressure of 200 pounds per square inch (14 atmospheres). This strange two-element tube is an ionization chamber and its function is to detect gamma rays in a new, sensitive system of radiation detection for aircraft. The rays penetrate the one-sixteenth-inch steel walls and ionize the enclosed gas. The collection of these ions within the electric field of the steel case and a central electrode provides a minute current. And that current is truly minute! At a radiation rate of 12 Roentgens per hour the current is less than one billionth of an ampere (0.8×10^{-9}). Obviously one problem presented the designers was to prevent any leakage current if an accurate indication from so feeble a current is to be possible. The high gas pressure increases sensitivity. The ionization chamber, intimately teamed with an electrometer tube that can amplify minute currents, provides an accurate detector for the measurement of radiation intensity.

Above: A tunable resonant cavity. Left: A high-pressure ion chamber.

Reference Cavity—One of the components developed for use with radar systems is the reference cavity. It is a precision-built vacuum device about the size of a child's building block, with small windows of glass. Interposed in microwave "plumbing" it permits passage of energy in only a fixed and narrow band of frequencies. Heretofore, these have not been adjustable. Currently, however, radar sets capable of operating over a band of frequencies are under development. For these, tunable cavities have been produced. These are adjustable over a frequency range of about 1000 mc. The task of making the size of the cavity adjustable has not been easy. The adjustment and setting indication are obtained by a micrometer-type dial.

Tunable Magnetrons—Adjustable-frequency radar sets must have adjustable magnetrons—the precision, multi-cavity generator of microwaves. A way has been devised for shifting the tube frequency electronically instead of mechanically. This is done by passing an electron beam down all the cavities and modulating the beam to achieve the frequency shift. This scheme is used to obtain tuning over a six-mc band for FM-type radar systems.

Large power tubes used to produce radio frequencies for broadcasting service and high-power industrial work, such as on tin-plating lines, have employed filaments of pure tungsten. Thoriated-tungsten filaments, while more efficient electron emitters, have not been sufficiently reliable. They are more sensitive to their environment and subject to damage by transients. A continuing program of filament development and improvement of its environment, however, has brought the thoriated-tungsten filament to a place of comparable reliability. It is now being used in the 100-kw tubes and effects a reduction of filament-heater power from 8 kw down to 3.

Vacuum rectifiers have been produced that are phenomenally small for their rating. A tube (the 6102) is about the size of a door knob (and much the same shape) but can withstand 40-kv inverse voltage when oil immersed. The air-cooled version (6103) is good for 20 kv. The forward rating is 150 milli-

The handful of miniature electronic components in the foreground is assembled in the frame at the left, coated with a heat-conducting compound, and formed in a mold (center) into a permanently sealed resin-encased electronic element with plug-in terminals.

amperes continuous or 950 maximum. These rectifiers are used as a source of d-c power for radar equipments.

A large *oil-immersed rectifier* has been developed for heavy-dust precipitation. It can withstand 140-kv inverse voltage. Being oil immersed it is immune to the troubles incident to dust and change in ambient conditions that beset the older air-insulated voltage rectifiers.

Plug-in Electronic Circuits—in Color

POPSICLES, the engineers call them. And aptly named, at that. They are rectangular objects about two inches by four and perhaps an inch thick, and in many pastel shades that make them look like the sticks of "ice" that delight the youngsters. But, instead of the protruding handle, at one end are several pin-type terminals. This suggests something electronic. They are. In fact they are complete electronic circuits, consisting of several sub-miniature electron tubes, resistances, condensers, and wiring, permanently encased in a block of colored plastic. The whole circuit is thus plugged into a socket like a vacuum tube. The colors make them attractive but are not for eye appeal alone. They identify the circuit it contains, and follow the international color code for resistances. Thus a serviceman can identify a unit by color alone without having to study the designation stamped on one side. Saves time, helps avoid mistakes.

Potting of electronic components, as the technique is called, is not new. But, even aside from the practical use made of color, it has been greatly improved. When the process was first used, two or three years ago, the energies were so low that heat dissipation was no serious problem. Now, however, components drawing larger currents are used.

Two approaches have been taken to the heat problem. A "potting" or plastic filling compound is chosen that has good thermal conductivity. Also sleeves of copper are placed around the tubes and connected by metal strips to a metal boss in the side of the unit. A screw fastens this boss to the chassis, serving thereby to give mechanical rigidity to the unit and to conduct much of the heat from the source (i.e., the tubes) to the exterior. By these means the heat-dissipation ability is improved by nearly 500 percent.

This plug-in, electronic-circuit unit technique can be applied to many types of electronic gear. In the particular case at hand it is being used for nuclear-radiation detectors. This is a central radiation-monitoring system to which indications of radiation intensity are brought from 15 stations about the area. With the establishment of nuclear-energy power sources, and laboratories, and the application of nuclear-energy power plants to vessels, the development of centralized radiation monitoring systems is becoming an important phase of electronic development.

Heating and Welding

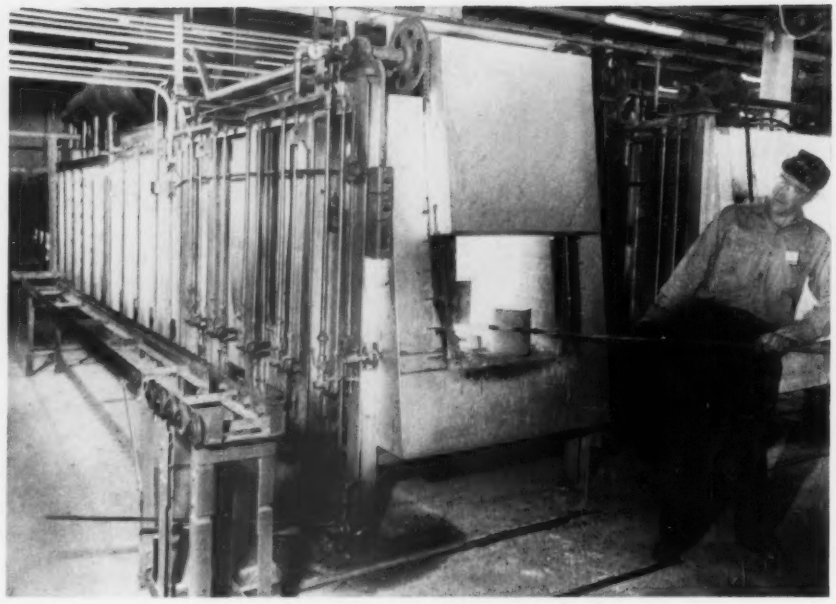
Making It Hot for Billets

THE YEAR just passed witnessed an interesting example of using high frequencies to heat metal for forgings. This is a comparatively new use of radio-frequency energy for heating. In this application the work consists of alloy billets about a foot long, weighing about a pound. They are roughly cylindrical but have two ball-like bumps near the center. These irregular-shaped billets are to be heated to 2100 degrees F for forging into gas-turbine blades. Use of high frequencies for forging is not new but is finding many new applications.

The high-frequency power for this task is supplied by four 150-kw, 9600-cycle motor-generator sets, which feed a total of ten work-handling machines. A walking-beam and escapement arrangement feed the billets through the work coil at the rate of one every 15 seconds. Special precautions are taken to prevent the billet from short circuiting the work coil. Also, it is necessary to heat the billets without heating the mechanism for handling them. A novel shape of carrier was developed in which two sets of currents are induced—but in opposite phase—and hence nullify each other. The carriers for the pieces to be heated are also made of very thin metal to reduce the amount of heat induced in them.

New Transformers for Induction Heating

TRANSFORMERS for use with motor-generator type induction-heating sets have been considerably improved. These units, because of the low power factor, must have continuous ratings of up to 750 kva even for 150-kw heating sets. Hence, cooling is a problem. The primary and secondary windings are cooled by circulating water through the copper-tube conductors. Low-loss Hipersil cores are cooled by water circulation through blocks placed in contact with the cores. A typical 750-kva induction-heating transformer occupies about 2.8 cubic feet and weighs about 150 pounds. By comparison, a Westinghouse type s, oil-immersed, single-phase, 60-cycle transformer of 500 kva occupies about 192 cubic feet and weighs about 5400 pounds.



This furnace used in a Westinghouse aviation gas-turbine plant is typical of those being required for heat-treating stainless-steel molds for investment castings. These alloys call for comparatively high temperatures—2200 degrees F, instead of about 1850.

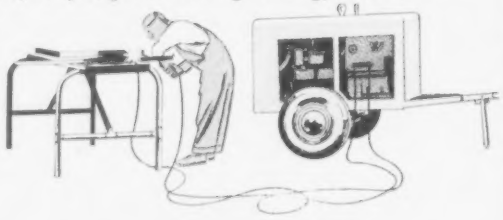
A Skyscraper Heat-Treating Furnace

ALMOST unusual furnace now being built for an aluminum plant will stand vertically as high as a 13-story office building. This vertical furnace will be used to heat-treat long, extruded aluminum shapes required primarily by airframe builders. Aluminum pieces 110 feet long will be suspended in the heat-treating tower, which stands about 130 feet high. At the conclusion of the heat bath, the suspended pieces will be dropped quickly into a water-filled pit of the same depth below the furnace for quenching.

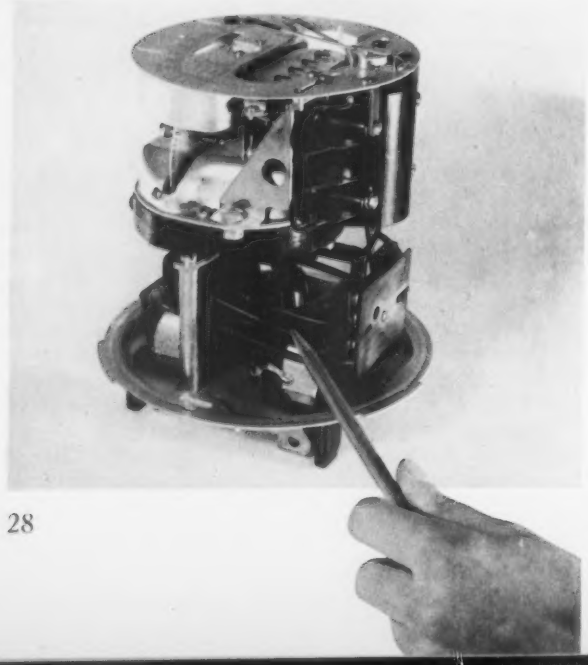
Vertical furnaces of this type were built during War II and a number of improved models have been constructed since. None, however, can accommodate extrusions longer than 60 feet. In these furnaces temperature must be held within close limits, i.e., 925 ± 10 degrees F. Also the temperature difference between the top and bottom of the tower must be slight. The 130-foot tower is being designed to provide a maximum temperature difference of less than five degrees. This is accomplished by rapid circulation of hot gas. In this furnace, combustion takes place in one tower and the hot air is passed into the top of the heat-treating tower that stands beside it.

A Welder and Power Plant on Wheels

A versatile new engine-driven generator is both a welder and an a-c power plant. It consists of a gasoline engine and a single generator. The generator has a commutator at one end, slip rings at the other. The set can supply up to 250 amperes for welding, or 3 kw of single-phase, 60-cycle power. During welding, the a-c end can also deliver a small amount of a-c power for, say, a few lamps. The unit weighs 1100 pounds and is mounted on two wheels.



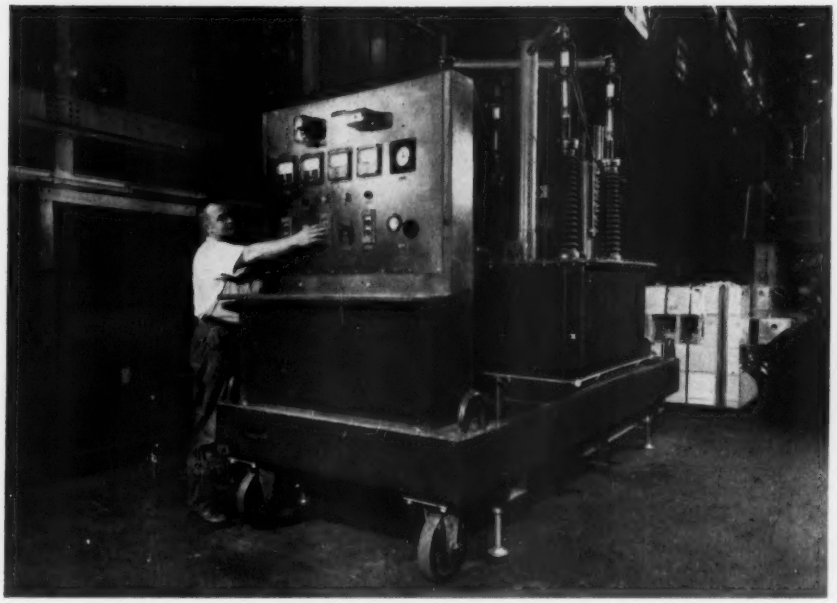
Measurement and Test



Bigger Loads Mean Bigger Thermal Demand Meters

THE 100-AMPERE thermal demand meter is no longer large enough to handle the growing loads of commercial establishments, and even some homes with high-installed electrical capacity. New thermal demand meters with 200-ampere ratings in both single-phase and polyphase varieties have been developed. These new meters incorporate the basic features proved successful on the 100-ampere size and have new features in addition. Insulation has been increased to give greater surge strength. A current transformer supplies both the electromagnet and the thermal element, making for easier repair and a cleaner assembly. These combination thermal demand watthour meters provide better accuracy with smaller transformers than their lower capacity predecessors.

Thermal demand meters for 200 amperes, both single phase and three phase, have been developed to meet growing domestic loads.



This mobile test unit delivers 125 kv at constant potential for making dielectric measurements of insulation.

←

A Smaller Oil-Dielectric Test Unit

A 120-pound unit for testing the dielectric strength of oil can be moved by two men. In that sense it is portable. But a 65-pound unit is more portable. One man can handle it. Such has been the reduction in weight of the standard unit for testing the dielectric strength of oil. This reduction by nearly a half comes about by a redesign that takes advantage of the better magnetic properties of Hipersil grain-oriented steel and by the design of a new case made of light-gauge sheet fastened by spot welding. Included in the controls is a relay that automatically disconnects the test set when the oil specimen breaks down. Voltage is controlled in small increments by a compact Powerstat.

High-Energy Surge-Comparison Tester

USE OF the surge-comparison principle to check the dielectric quality level of coils and circuits has become widely accepted since the introduction of the surge-comparison tester about three years ago. With this system the coil under test and a standard or comparison coil of known quality are subjected alternately and rapidly to an accurately controlled electrical surge. The resulting wave shapes are cast upon an oscilloscope screen for visual comparison. If the two coils are alike, the wave shapes essentially coincide. If the test coil possesses faults or serious weaknesses the shape of its wave, by comparison with that of the standard, discloses them.

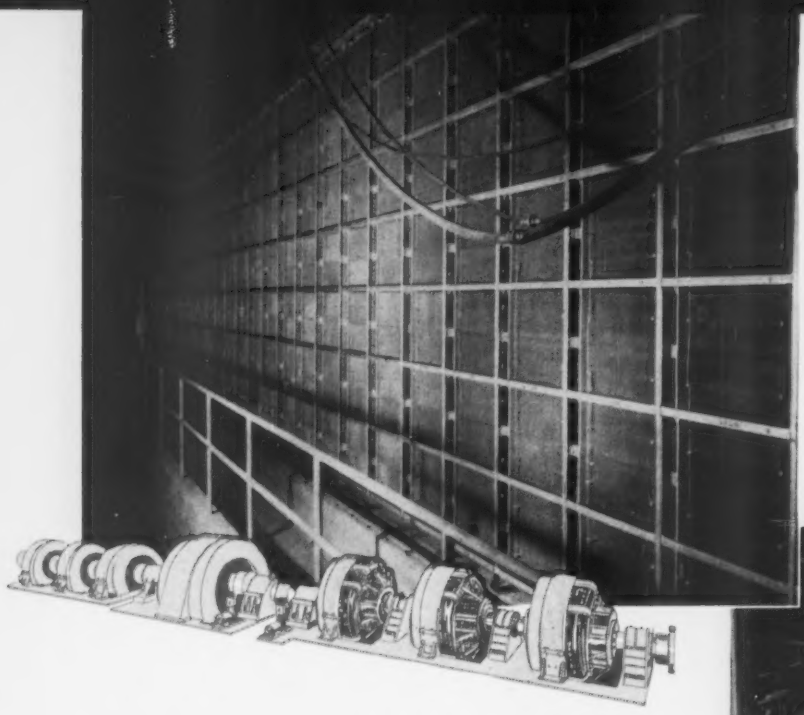
Under normal operating conditions the output of the standard surge-comparison tester is deliberately limited to 100 amperes instantaneous peak output at 10 kv to protect the triggering thyratron in the condenser discharge circuit. This is ample for the bulk of factory and repair-shop testing of motor and generator coils and similar purposes. However, for testing the coils of large generators and other low-impedance circuits, surges of much greater energy are necessary. To provide these for testing its own large generators, Westinghouse engineers have built a special surge-comparison tester employing ignitrons that can deliver 10 000 amperes at 12 kv. This special-purpose test unit develops a surge with peak energy 120 times greater than the commercially available models. This high-energy tester is used on turbine and waterwheel generators as they are assembled.

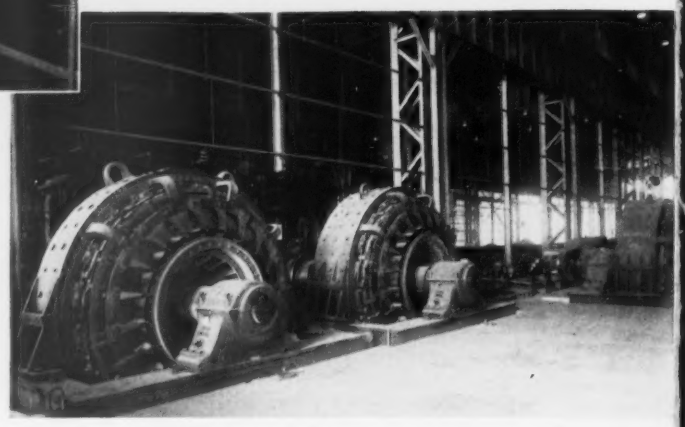
High-energy surge-comparison set used to check generator coils.

Better Materials, a Smaller Vibrometer

ENGINEERS have taken advantage of recent improvements in related fields to make a recording vibrometer that utilizes smaller pickups. These pickups have a probe that rides on the machine being monitored. One end of the probe has a coil free to move within a strong field of a permanent magnet. Any movement of the probe results in a voltage induced in the coil. This voltage depicts the vibration both as to magnitude and frequencies. By using a smaller magnet, but larger amplifier, the weight of the vibrometer pickup has been cut from about 27 pounds to 5 pounds, and the volume from about 310 cubic inches to about 90. The smaller size makes it feasible to use the vibrometer more widely as an operational tool. For example, it might be used on higher speed machines, such as gas turbines, that require physically smaller pickups to follow the vibration.

Metal Working





Fairless Works equipments: left, a portion of the 210 000-cfm Precipitron air-cleaning equipment; below, three of the hot-strip mill motors; color, the 7-unit, 83-foot, slabbing-mill motor-generator set.

Fairless Superlatives

THE FAIRLESS Works of the U. S. Steel Company rightfully catches the imagination. This all-new, integrated plant adds 1 800 000 tons to the nation's annual steelmaking capacity. It is being built on farm land bordering on the tidal Delaware River between Pennsylvania and New Jersey. The Fairless Works is particularly significant for its great size and numerous examples of modern engineering. Everything about it commands the superlative.

The total connected load adds to 390 000 kw. The figures for the equipment supplied by Westinghouse alone are astonishing. For example, the transforming equipment totals 300 000 kva—ranging in size from 100 to 50 000 kva. The Precipitron equipment cleans 3½-million cubic feet of motor-room air per minute. That's 750 tons of air hourly, which is at least twice and perhaps three times as much as for any other mill. To move this mass of air calls for 146 Silentvane fans driven by motors totaling 3717 hp.

The 45-inch slabbing mill rolls ingots down to slabs as much as 74 inches wide. This requires a 12 000-hp, double-armature, twin-motor drive for the horizontal rolls and a 4000-hp motor for the edger, which makes it the most heavily powered slabbing mill in the world. The d-c power for it is provided by the largest flywheel motor-generator set ever built. The flywheel, the 8000-hp induction motor, and six generators total 83 feet in length and weigh 300 tons. The m-g set runs at a speed of 505 rpm, which is fast for such a machine. At this speed and mass the total stored energy is 250 000 hp-sec (or about 70 hp-hr). The auxiliaries for the slabbing mill require 77 motors, with the sizable total capacity of 10 740 hp.

Indicative of the dependence that must be placed on automatic controls for the integrated operation of such a giant plant, a total of 58 regulating devices is employed. Of these, 51 are Rototrol rotating regulators, the remainder are Magamp, Silverstat, and electronic regulators.

The 40-inch blooming mill is driven by an 8000-hp motor. Its speed is higher than common, 65 to 130 rpm.

The 80-inch hot-strip mill is significant in several respects. Its output speed is 2330 fpm, which is unusually high. The six stands are driven by five 5000- and one 4000-hp motors for a total of 29 000 hp, itself a record. The electrolytic strip-cleaning line for the hot-strip mill calls for 50 motors with an aggregate horsepower of 2694.

All d-c power for the hot-strip finishing-mill drive motors is supplied by six ignitron rectifiers. The electrical system is divided into three sections, to keep the short-circuit current within the limits of practical, low-voltage, circuit-breaker capacities, and to provide extra flexibility of operation. Two motors and two rectifiers are tied to a common bus, forming one unit. The voltages of the three bus sections can be adjusted independently, but once adjusted the voltage of all three sections can be controlled simultaneously from zero to maximum setting without disturbing the preset relation.

The 80-inch skin-pass mill, likewise, is noteworthy as to its power requirements. Two 300-kw drag generators maintain tension on the feed reel. A pair of 600-hp twin motors drives the rolls, and a 1600-hp, double-armature motor drives the winding reel.

The switchgear for such an enormous operation also makes an impressive figure. Westinghouse supplied modern switching equipment for the 132-, 69-, and 13.8-kv systems that serve the plant and distribute power within it. This includes, among many other components, 138-kv circuit breakers of 5-million-kva interrupting capacity, and over 100 metal clad breaker units containing breakers with interrupting capacities of half-million-kva.

A Quarter Century of Progress in Hot Mills

SELDOM is the inexorable advance of technical progress as well illustrated as by the case of Armco Steel Corporation's hot-strip mill at Middletown, Ohio. When built in 1927

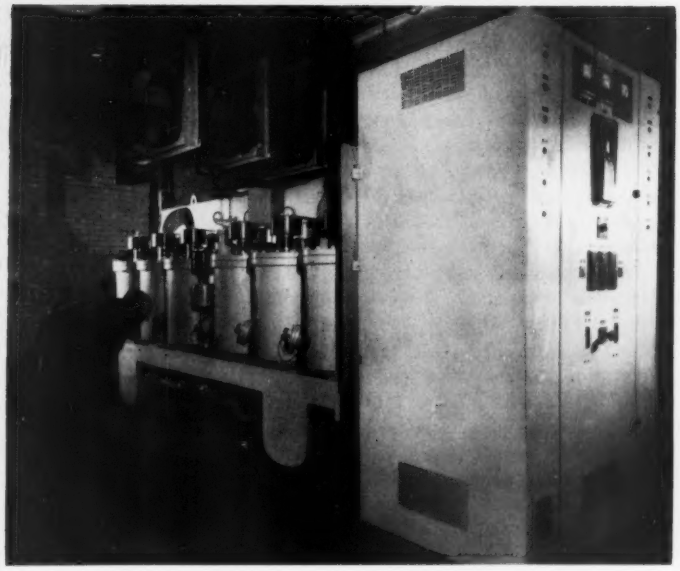
it was one of the first of the modern wide hot-strip mills and represented the best thinking in mill design. The four finishing stands were each powered by a 3000-hp motor, giving a maximum delivery speed of 988 fpm for 56-inch sheet.

Armco (then the American Rolling Mill Company) was, from the start, determined to keep the mill as up to date as possible. The mill has been revamped in major fashion twice. The second was completed last year. In 1937 one more stand was added. In 1939 a sixth stand was installed, driven by the four original 3000-hp motors. Two 4000-hp motors were applied to stands Nos. 2 and 3, and a 4000-hp m-g set added.

Last year power was again increased. The six stands are now driven by three new 4500-hp motors, the two 4000-hp machines and one of the original 3000-hp motors. Thus in a quarter of a century the finishing mill power has doubled—from 12 000 to 24 500 hp—by which the mill can deliver a strip 80 inches wide at about 1800 fpm instead of a 56-inch strip at 988 fpm.

This latest addition of motors requires also an increase in the d-c power supply. But the motor room was now too crowded for more m-g sets. Instead, two ignitron rectifiers delivering 5000 kw were installed. Because these are comparatively light in weight and are non-rotating they require no heavy foundation or large floor area.

This ignitron in parallel with m-g sets serves a rolling mill.



Magamps Control a Cold-Reduction Mill

THE MAGNETIC amplifier is given the full control job in a new large four-stand tandem cold-reduction mill of the Pittsburgh Steel Company at Allenport, Pa. Magamps control all the regulating functions on all the voltage regulators for the four stands and for the winding reel. Three of the four stands are driven by duplicate twin motors, each consisting of two 2250-hp, 200/450-rpm units. Gears are necessary for space reasons, hence all motors can be designed for the same speed range, the different speeds on the mill rolls being obtained by gears of different ratios. The fourth stand is driven by a 1500-hp twin motor. This is believed to be the first time all stands of a cold mill have been driven by twin motors.

Ultra-Fast Reversal of Slabbing Mill

IN A SLABBING mill, a red-hot ingot weighing about 30 000 pounds is sent through the rolls, whereupon the rolls are repositioned and reversed for the return pass. This is repeated until the ingot is reduced to a slab 4 to 8 inches thick, and up to 60 inches wide. The trend in mill design has been to reduce the time for reversal as much as possible, because the less time spent in reversal the greater the production.

The new blooming mill at the Southside plant (Pittsburgh) of Jones & Laughlin Steel Corporation has set a new record for fast reversal. The 10 000-hp twin motor reverses from 40 rpm in one direction to 40 rpm in the other direction in just one second. It is an amazing sight to watch these two giant motors turning smoothly at full speed in one direction, and, one second later—with no visible strain, no perceptible vibration—see them running with equal calmness in the opposite direction. This record speed of reversal is made possible by Rototrol regulators that provide high forcing voltages to the main machine exciters.

For fast reversal of the roll motor to be of any value, the auxiliaries must also act rapidly. These include the main-roll screwdown apparatus, the mill-table motors, and the manipulators. Indicative of the high speed of auxiliary operation is an incident that occurred as the mill was undergoing its initial tests. The manipulators are used after a pass to turn the slab over on its side. When they were first tried they operated so quickly that the 10-ton chunk of metal was flipped completely over, i.e., 180 degrees instead of 90.

During the first few weeks of operation it was necessary to slow down all of the adjustable-voltage auxiliary drives. As the operators become more familiar with the new equipment, the speeds will be increased to take full advantage of the fast operation of which the mill is capable.

One component contributing importantly to the fast reversal action on the mill-auxiliary drives was a special Rototrol rotating regulator. By reducing the air gap about half compared to that in standard machines, and by a coordinated design of the Rototrol regulator and adjustable-voltage generators, the system sensitivity was increased approximately eight to one. Also the motors are built with laminated frames to enable the motor-field flux to change at the maximum rate.

Paper...

A Suction Pickup System Speeds Up Newsprint Production

A WEB OF embryonic newsprint as it comes off the wire or forming section of a Fourdrinier machine is about 80 percent water. This soggy film of pulp has no more strength than you would expect it to have. The problem is to transfer this fragile sheet from the forming section to the first press section. This has been a precarious business fraught with frequent breakages and limited speeds that play hob with the mill's tonnage totals. Recently a scheme has been developed that makes it possible to handle the frail sheet with ease and to increase production speed.

This suction pickup and transfer system, developed by Beloit Iron Works, does not rely on any strength in the web. Rather the wet sheet is carried from the wire, where it is

Two devices—one very old, the other ultramodern—team together to provide a fast-response, highly stable speed regulator for sectional paper machines. One is the mechanical differential, which was the basis of one of the earliest paper-machine regulators. The other member of the team is the magnetic amplifier, which is a means of obtaining high amplification without moving parts. The unit contains a set of cone pulleys, driven from the section of the machine whose speed is being regulated, a synchronous motor driven at a speed proportional to the master-reference speed, and a differential-gear system for detection of speed difference between the cone pulley and the synchronous motor. This difference is converted to electrical signals, rectified, amplified, and applied as a correction to the driving motors. Under steady-state conditions the only moving components are the pulleys, gearing, and synchronous motor.

formed, by suction to a felt blanket, to a transfer section, and from there by suction to another felt that delivers it to the beginning of the drying sections. All this is done at speeds of 1600 fpm, and it may prove possible to produce newsprint at speeds over 2000 fpm. (Fifteen hundred fpm is the common speed on modern newsprint machines.)

The motors driving the rolls of the transfer section must obviously run in exact synchronism with the remainder of the block-long newsprint machine. With the first main press acting as the speed tie for the transfer section, an additional three-motor helper drive is applied together with a power supply m-g set and a Rototrol regulator to maintain constant helper-motor torque.

This improvement in newsprint manufacturing is expected to have benefits both as to cost and quality of product. It appears that the sulphite content can be reduced, perhaps by one third, thus producing a greater yield per ton of pulp. Also, the process promises to make possible a lighter weight sheet while still retaining satisfactory quality.

Man-Made Fibers—Tops in Precision Control

THE HIGH-WATER mark in precision process control to date is probably established in the manufacture of man-made fibers. These filaments are formed by forcing a liquid through the many holes of a spinneret and collecting them on drums or spools after they pass through a bath of air or coagulating acid. The slightest variation, either in the rate at which the

Textile, Petroleum,

Electronic regulator for controlling speed of man-made fiber drive to within 0.1% of constant.

filaments are formed or the tension under which they are held, has a marked effect on filament size and, to an extent, on their physical properties. Fabric knit from these materials clearly shows these variations and hence is worthless. Precise speed control is, in this business, an absolute must.

There are many fibers, with different details of production. However, a representative drive consists of a one-hp motor driving a constant-displacement pump that extrudes the liquid through the tiny holes of a spinneret; the many fine filaments thus formed are gathered into one strand in a single wrap around a capstan or feed wheel driven by a one-fourth-hp motor. The product is wound up on a spool driven by another motor. The speeds of the pump and feed-wheel motors must be independently adjustable over a six-to-one range, but must remain constant to within one tenth of one percent at any selected speed. All pump motors must run in exact synchronism with each other. The same is true of the feed-wheel motors.

Such precise speed regulation is maintained by special electronic regulators. The pumps and feed wheels are driven by synchronous motors, which run at speeds determined by the frequencies of their respective power supplies.

The motors operate from adjustable-frequency power supplies provided by pairs of motor-generator sets that convert alternating current to direct current and back to alternating current again. This double transformation isolates the drive from fluctuations in the supply system.

Pipeline Progress

ONE OF the most flourishing of businesses is the nation's pipeline transportation system. New and larger lines are being built, some older lines are being enlarged or repowered, and many are adding modern features to increase productivity or safety.

The West Texas Gulf Pipe Line represents new con-

Chemical

Breakers used in the anode circuit of electrolytic-plant rectifiers have been increased in rating from 2170 amperes, 750 volts to 3000 amperes, 1000 volts with no increase in arc-interruption time.

← A new high-capacity textile spinning frame requires a drive motor that by comparison with older ones has more horsepower, is physically smaller, and radiates less heat. The motor specially built for this application has supporting arms instead of height-consuming feet. To increase the horsepower output and to reduce the surface temperature of the frame a water-cooled heat exchanger is built into the end brackets. Each consists of a spined coil of copper through which is circulated two quarts of water per minute. An internal blower maintains rapid air circulation. Although the motor stands only 14½ inches high (1⅜ inches less than the standard 15-hp motor) it develops 20 horsepower.

struction. Extending 440 miles, almost across Texas, it consists of 26-, 24-, and 20-inch pipe. Its 26-inch section is the largest diameter liquid-petroleum line in the United States. This line makes the most extensive use of centralized control and the largest amount of horsepower in any single electrified station. One station contains motors totaling 14 000 hp.

Microwave Communication—Two of the biggest problems in pipeline operation are communication between stations and control of equipment at booster stations. The electrical engineer is coming forward with solutions to both. For the first he is offering the most modern of communication techniques—microwave. (See also p. 13.) By this system a wide variety of information, including voice, is transmitted through space from one visible point to another at frequencies of one or two thousand megacycles (i.e., radar frequencies). Among such information so transmitted are supervisory signals for the control of pumps and other apparatus at unattended pumping stations.

An installation of the recently developed microwave apparatus for this purpose is being made on the Plantation Pipe Line Company's system. This covers 156 pipeline miles between Bremen, Georgia, and Athens, Tennessee. This distance will be covered by four microwave terminal stations and three repeater points. The system can provide up to 30 duplex voice channels or telegraph channels, in simultaneous operation, of which 13 will be used initially for communication, telemetering, and for supervisory control of the equipment at two new unattended booster stations, added to increase line capacity. Each booster station will be controlled from the existing upstream station. By supervisory control over microwave, the 600-hp pump at each station will be started and stopped and the associated valves operated in the proper sequence. Also the operators at the controlling stations will be provided important information about the state of things at those booster stations, each approximately 50 miles away, including indication of valve positions, warning of the functioning of any motor and pump protective equipment, of excess leakage from pump seals, of improper ventilation in the motor room.

Pipe-Scraper Detection—It is common pipeline practice, at intervals, to send a scraper through a pipeline to remove scale and accumulation inside the pipe, which builds up flow resistance. It is obviously necessary to be able to follow the travel of the "pig," as it is called. It must not, for example, be allowed to travel into the piping of a station. Either the scraper must be removed from the line on the upstream side and reinserted on the downstream side or, as it approaches, the station must be shut down so that the scraper takes a bypass circuit.

A new method has been devised for detecting the scraper location. This system requires no projections into the pipe. It is an electromagnetic device, requiring only a few watts to operate. This simple device can be set up to require no action on the part of a station operator, or even the presence of an operator at an unattended station. It can activate the controls itself, giving a signal of that action. Or it can be used at intervals throughout the line to provide the dispatcher with frequent indications of the "pig's" progress.

A new vibration-sensing relay gives an added measure of protection to equipment at unattended stations. Applied to centrifugal pumps it provides a warning of a bearing failure, an unbalanced impeller, or a rubbing rotor. It consists of an acceleration mechanism responding to vibration at the frequency of the pump speed, and arranged to close a tripping contact when the vibration exceeds a predetermined amplitude. The mechanism is pivotless and free of wearing parts.

Bigger Power Supplies for More Aluminum, Phosphorus

WHAT IS happening in the *production of aluminum* can be read in the present activity of those producing the power equipment for the country's new "pot" lines. Whereas the War II aluminum plants required a maximum of 60 000 amperes at 645 volts, many of the new ones utilize currents of 75 000 amperes at voltages of 750; some, 125 000 amperes at 800 volts.

For these electrolytic lines of higher current and voltage, rectifiers of larger rating have been necessary. This has meant a redesign of ignitron tubes. Whereas a rectifier operating with 12 tubes in 6-phase connection delivered 5000 amperes at 645 volts, it now provides 6000 amperes at 750 volts, a 40-percent power increase.

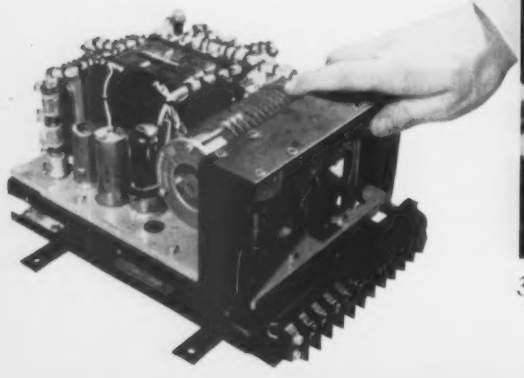
The higher current and voltage of aluminum electrolytic lines have made it necessary to develop a circuit breaker of greater rating to interrupt rectifier arc-back currents. The new anode breaker can handle currents of 3000 amperes at 1000 volts, which is 85 percent more energy than the previous ratings of 2170 amperes at 750 volts. This increased rating is significant when the operating speed is considered. Anode breakers limit the fault current in 0.7 cycle and clear it in one cycle. The larger the breaker, the heavier the contacts and other members of the moving mechanism must be, which makes such fast operation more difficult.

Transformers for electrolytic plants, accordingly, are larger: 8325 and 9000 kw instead of 6500 kw of those built ten years ago. These are not large as transformers go but they are bigger than their rating indicates because of the larger physical parts inherent to rectifier-circuit service. Extra heavy bracing must be provided to permit the winding to absorb the shocks that attend the random-occurring ignitron-rectifier arc-backs, which appear to the transformer worse than short circuits.

The *elemental-phosphorus industry* is likewise growing at a rapid clip. Until a year or so ago the largest transformer for supplying power to phosphorus electric-arc furnaces was one of 12 000 kva. Last year, units of 15 000, 17 000, and 27 000 kva were placed in service. These are in the large new phosphorus plants in Idaho.

Aviation

The Chance-Vought "Cutlass" is powered by two Westinghouse J-46 engines. Below and right: a voltage regulator and a row of 20-kva alternators for a new single-phase, 380-to 800-cycle electrical system for aircraft.



Technical and Production Progress with the Jets

THE ABILITY of Westinghouse both to produce jet engines in numbers and to undertake technical developments quickened materially in 1952. The engineering staff was increased by half. The full effect of the 86-acre Kansas City manufacturing plant, recently converted to jet-engine manufacture, became available during the year and enabled the total production of Westinghouse jet engines to date to pass 5000 a few months ago. Also, within the near future, addi-

tional production help will come from the huge component plant being erected near Columbus, Ohio.

The new Westinghouse J-40 turbojet was qualified in 1952 for quantity production. It is believed to be the most powerful, completely qualified turbojet engine in the world. This engine has been selected as the power plant for many of the Navy's fast new fighter planes.

Details as to types of engines in production and their performance remain restricted. However, thrusts being achieved are fantastic by comparison with the most optimistic expectations when the American jet industry came into being in 1941. Although fuel consumption and weight for a given output have steadily improved, the demand for further improvements is great, and is consuming much engineering effort.

Flight testing by the manufacturer is helping materially to shorten the time between drafting board and assembly-line airplanes. Westinghouse's Aviation Gas Turbine Division is operating two twin-engine Douglas F3D-2 "Skyknight" Navy jet fighters and in a few months will add a four-engine North American B-45 "Tornado" Air Force jet bomber to its test fleet. These test planes have a place of great importance in the development of a new engine. As matters have stood, components of a new design are individually tested in the laboratory. Large assemblies are later tested in the laboratory and as a part of an engine in test cells and in altitude chambers, to simulate the low pressures and low temperatures corresponding to high-altitude flight conditions. Finally the complete new engine undergoes months of extensive operation in test cells and altitude chambers, terminating with a 150-hour qualification test. This gauntlet run, the engine can be turned over to an air-frame builder. It is a long process and, in spite of every effort and costly facilities, it does not expose all the "bugs" in a new design. Experience shows that actual flight is the most positive test. The ability to take a new engine, or even an altered component of a production or semi-production engine and operate it on a flying test bed under all service conditions ahead of type testing is important. It permits improvements to be made readily, without having to wait the months necessary to pass a complete engine and have it tried by the Services.

To the public a lot of glamour still clings to the jets. However, to those in the engine laboratory and design department, jets simply mean intensive work at high pressure to create a major improvement here, a small gain there. A few random technical advances show the character of this work.

Titanium now is assured of a place in jet engines. But this point has been reached only because metallurgists in Westinghouse and a few other companies were convinced that, in spite of tremendous obstacles to the production and use of titanium, the advantages to be gained were outstanding.

Titanium has three qualities that grip the attention of jet men: (a) it weighs but two thirds as much as ferritic materials and is equally strong; (b) it retains its strength up to about 800 degrees F, which is far above the limiting temperatures for aluminum; (c) titanium is almost completely unaffected by salt air and water—much more so than is aluminum. Even after the Du Pont Company and others solved the knotty problems of winning the metal from its ores and at a cost within bounds, problems of how to machine titanium threatened to wreck the program. Titanium cannot be cut by ordinary techniques; it smears on the tool. Jet-engine metallurgists found the answer, partially, to lie in machining the material at a low temperature, created by bathing the tool and the work in a stream of evaporating carbon dioxide (—112 degrees F.)

A 6000-rpm, "constant-frequency" 40-kva single-phase alternator.

The problems of using titanium-alloy for jet compressor discs have been solved. Engineers are now working to reduce the cost, which is still high. Also, development work to use titanium for compressor blades is well underway. It appears that pure titanium metal, rather than an alloy, is preferable for blades. Titanium for blades, in addition to its salt-air corrosion resistance, has a twofold advantage accruing from its light weight for a given strength. The blades themselves are lighter, and also because they are lighter and hence introduce much lower centrifugal stresses, the compressor discs to which they are fastened can be made lighter.

A vast amount of work has been done on *afterburners*, a means of obtaining about 40 percent more thrust for take-offs and almost 100 percent more thrust for actual combat by burning raw fuel, mixed with the engine exhaust air and gases, in a duct aft of the engine. Burning this fuel raises the temperature of the exhaust gases, greatly increasing their velocity through the exhaust nozzle and thereby increasing the thrust. Westinghouse engineers have devoted much effort to the improvement of combustion efficiency, reliability, and control, and to increasing the operational altitude and thrust levels. A great deal of the early work was accomplished in the famous Lockheed F-80 and XF-90 airplanes and is being continued in Chance Vought F7U airplanes, using the J-34 engine.

One of the most important criteria of turbojet design is the ratio of thrust to engine weight. The lighter the engine, for a given thrust rating, the lighter the empty airplane and the greater its payload, fuel, or armament capacity. One of these important developments—not yet complete—is the use of *hollow blades* fabricated of sheet metal instead of forged or cast solid metal.

The Growing Family of Aircraft Alternators

TO MEET the ever-growing requirements of aircraft for more a-c power and for special-purpose a-c power, new alternators are being developed. The largest one to date develops 60 kva, 3 phase at speeds between 5400 and 6600 rpm. It is an 8-pole machine, which gives a nominal 400 cycles ± 10

percent, which is constant frequency in aircraft parlance. It can deliver 150-percent load for 5 minutes and 200 percent for 5 seconds. The weight is 123 pounds. This alternator meets all requirements for low harmonic content in the output voltage wave—a requirement made necessary by much of the electronic equipment served.

As kva rating rises the design difficulty increases rapidly. Additional rating calls for a rotor that is larger in diameter or longer, or some of both. To increase diameter vastly increases the centrifugal forces at which these machines run (they must pass overspeed tests from 9000 to 11 000 rpm). If length increases, cantilever forces and vibration become troublesome as these alternators, being overhung from the engine shaft, are supported only from one end.

A 6000-rpm, 40-kva alternator, now in quantity production, has a number of new features. The poles are not separate entities fastened to the rotor. The punchings for the eight-pole field are cut from a single sheet. This gives the salient-pole rotating field greater strength, prevents poles from loosening on the shaft, eliminates any indefinite or changeable airgap where the poles fasten to the shaft, and maintains the gap between the stator and the rotor more constant. The generator has a one-piece shaft, an improved torsional-vibration damper, and an aluminum housing instead of one of magnesium to raise the natural frequency. The machine has been tested on overspeed to 11 000 rpm.

A-C Systems for Aircraft Progress Rapidly

THE A-C power-supply system for aircraft is rapidly catching up to its much older d-c brother in becoming an integrated system of generation, regulation, control, and protection. Last year such a coordinated system occurred for 20 kva, single phase.

The alternator operates over a wide speed range, from 3800 to 8000 rpm, and delivers power varying frequency from 380 to 800 cycles. It is used in large planes to serve loads that can use any frequency, such as wing and window heating, lighting, the pantry, and certain electronic loads. The generator is suited for operation at altitudes up to 50 000 feet.

The control panel for this 20-kva system brings for the first time to alternating current the same integration of elements provided some time ago for the more fully developed d-c system (see below). Combined into one plug-in unit are the relays for protection against overvoltage, ground faults, low frequency, and for controlling the exciter field.

The regulator consists of an electronically trimmed carbon pile that provides extremely good voltage control—to 1½ percent in contrast with 2½ ordinarily guaranteed with carbon-pile regulators. In case the electronic-trimmer circuit fails, the regulator reverts to straight carbon-pile control.

With ordinary systems of this frequency range, short-circuit current at maximum speed would be several times that at minimum speed. Voltage transients would be excessive when a short circuit is cleared at high speed, damaging electronic gear. The regulator incorporates a current-limiting device maintaining, say, 200-percent short-circuit current at any speed. This is sufficient to blow fuses, but limits the voltage transient to a safe value.

D-C Aircraft Generator Amperages Increase

THE CURRENT output of 30-volt d-c aviation generators has now risen to 500 amperes. Units of this rating have been built for ground use, to start airplane engines for example. This generator, which weighs 76 pounds, develops 500 amperes throughout the range of speed from 4000 to 8000 rpm and has, on test, demonstrated its ability to provide 1000 amperes for three cycles of one minute on and one minute off. This machine has required special brush rigging to handle the heavy currents, and special means for cooling the commutator. While this machine is for ground use only, an airborne version is under development. The largest d-c generator in quantity production is rated at 400 amperes. An experimental 400-ampere generator is only 6½ inches in diameter and 15 inches long, and weighs about 60 pounds. It employs extended risers from the commutator to ease the ventilation problem.

The double exposure shows an aircraft ejector tray and the action required to lock or unlock a unit. Right: a Magamp a-c voltage regulator.

The new standard control panel for d-c aircraft systems combines several elements on a single plug-in chassis mounted on a base of die-cast aluminum. Among the major components compacted into the 6 by 6 by 15 inches are: a carbon-pile voltage regulator, a differential relay, ballast lamps, ground-fault protection, a new generator-field relay, and a circuit breaker capable of interrupting 50 amperes at 175 volts with the plane at an altitude of 50 000 feet.

Magamps Make Possible Major Advance in Aircraft Alternator Regulators

IF THE planner of aircraft electrical systems were asked what he would like in the way of a voltage regulator for an alternator, he probably would call for zero weight and zero space. More hopefully he would also request the complete absence of moving parts, the use of no components with limited life, lasting stability in performance, complete indifference to temperature, altitude, and humidity changes and to fungus, vibration, and acceleration. Doubtless he would also specify that the regulator require no special skills or training by those who install and operate it.

Zero weight and volume are still a little hard to meet. But an alternator regulator has been produced that can say "yes" either completely or substantially to these other requirements, which seem almost equally impossible. This is because of the Magamp magnetic amplifier.

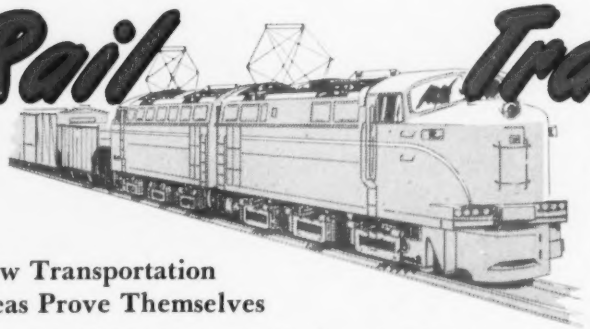
This new regulator has no moving parts. It does not include even a latch. The regulator has no electronic tubes, glow tubes, or hot-wire devices that have limited life. Magnetic amplifiers, selenium rectifiers, transformers, and other basic components that comprise the regulator are essentially unaffected by altitude, humidity, acceleration rates, and shock. In fact, the usual vibration-absorbing mounts have been eliminated. Temperature has some influence on every electrical device, but with the components used on this regulator the effects can be made negligible. The regulator inherently possesses everlasting stability of electrical performance; these characteristics do not drift, as is possible with tubes and carbon piles. The regulator has but a single screw adjustment. No critical adjusting procedure, no calibration chart must be mastered by field personnel.

Even the prototype of the new regulator weighs but 15 pounds, which is but 2 pounds more than the one it replaces. (And doubtless engineers will learn how to prune this a bit by production-line time, although they won't yet admit it.) This one regulator, furthermore, is interchangeable physically and electrically with the carbon-pile regulator over full range of 400-cycle alternator ratings, from 15 to 90 kva. It can be used with any constant-speed alternator Westinghouse has built or has under development.

A Standard Mount for Aircraft Control Units

A NEW DEVICE called an ejector tray is so simple that its significance as a major development in electrical equipment for aircraft might well be overlooked. It is a tray of aluminum 6.5 inches wide by 16 inches long and is the platform or support for any of several a-c or d-c control panels or regulators of the plug-in type. The tray is mounted permanently in the airplane. To place a device—say a voltage regulator—in position it is simply set on the tray. Turning the handle forces the regulator unit back so the plug terminals engage, and holds it there under positive spring pressure. It cannot shake loose because of loosening of a clamp. To remove the regulator, the handle is turned in the opposite direction. This forces (ejects, hence the name) the unit forward until the pins clear, after which it can be lifted out. A 30-pound disengaging force is developed with eight pounds of handle pull. It is as simple as that. The tray is polarized so only the right device can be plugged into it.

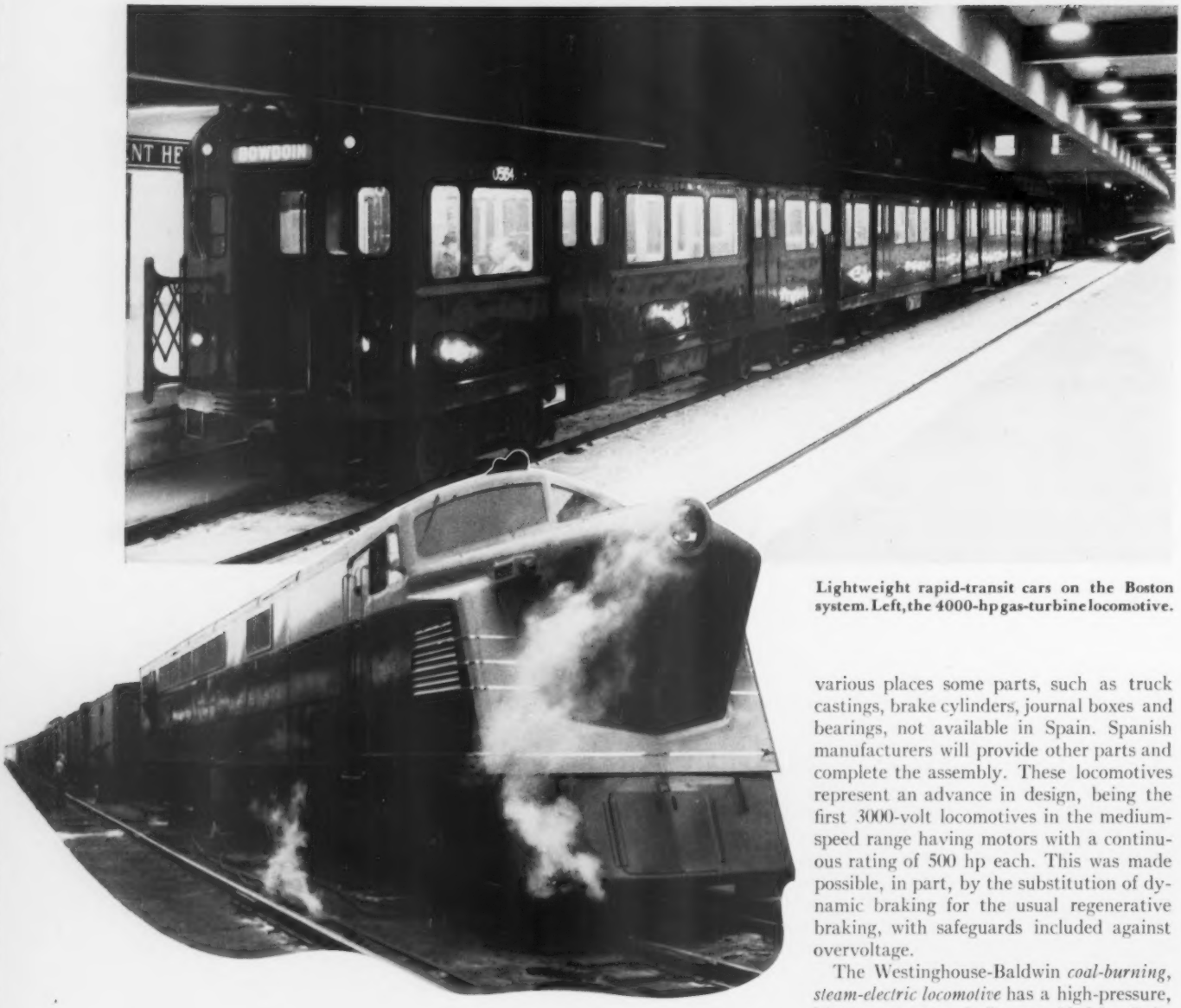
Rail Transportation



New Transportation Ideas Prove Themselves

THE TWO 6000-hp *ignitron-rectifier locomotives* have been in service a year. By last November 1 the two had rolled up 100 000 revenue miles of almost flawless performance on the Pennsylvania Railroad. No fundamental equipment deficiencies have appeared, in spite of the fact that these locomotives have consistently hauled heavier loads than are entrusted to any of the regular fleet of freight locomotives. Service experience indicates the locomotives are very economical of power.

The rectifier type of power supply for railroad service was given its pre-locomotive, in-use test on a multiple-unit car operating in suburban service out of Philadelphia. This car as of last October had been in service 40 months, had traveled 72 000 miles—all with the original tubes. Ignitron tubes are readily able to operate under the vibration and shaking of normal railroad service. This was well demonstrated one day



Lightweight rapid-transit cars on the Boston system. Left, the 4000-hp gas-turbine locomotive.

when the car developed a flat wheel that made the car uncomfortable to ride in but had no noticeable effect on rectifier-tube performance.

With this substantial proof of the soundness of rectifier supply for d-c motors from an a-c circuit, the New York, New Haven, and Hartford Railroad purchased 100 multiple-unit cars so equipped. Over part of the run these cars will operate under an 11 000-volt, a-c trolley. Near and in New York City, power will be taken from a third-rail, 650-volt, d-c circuit. Rectifiers are particularly suited for this application, making possible the use of d-c motors with their advantages over the single-phase commutator motor.

Twenty 3000-hp *electric locomotives* for the Spanish National Railway's 3000-volt, d-c system will be truly international in character. The electrical equipments for these locomotives are being built by Westinghouse in East Pittsburgh. Design of the mechanical parts is being furnished by the Baldwin-Lima-Hamilton Corporation, while the Westinghouse Electric International Company is obtaining from various places some parts, such as truck castings, brake cylinders, journal boxes and bearings, not available in Spain. Spanish manufacturers will provide other parts and complete the assembly. These locomotives represent an advance in design, being the first 3000-volt locomotives in the medium-speed range having motors with a continuous rating of 500 hp each. This was made possible, in part, by the substitution of dynamic braking for the usual regenerative braking, with safeguards included against overvoltage.

The Westinghouse-Baldwin *coal-burning, steam-electric locomotive* has a high-pressure, high-temperature boiler provided by Babcock & Wilcox of a type entirely new to railroad service. It is expected to go into trial service on the Norfolk & Western Railroad early this year.

Diesel-electric locomotives are "catching on" abroad as they have in the United States. This, however, has required the development of special motors for most of this service. Because track construction abroad is generally lighter, the heavy axle loadings common in the United States are not possible. This necessitates a motor of maximum output for its weight on 36-inch wheels instead of the usual 40- or 42-inch wheels. Often three axles are used per truck instead of two. Some locomotives, in addition, must be built for meter gauge (i.e., 39 inches instead of approximately 56). This reduction in motor length is a considerable design handicap.

In the *light-traction* field it is interesting to observe the expanding use in rapid-transit service of lightweight cars, with motors and control patterned much after that used on PCC cars. This idea had its first large-scale application two years ago in Chicago. This system now has 200 Westinghouse-

equipped cars. Last year the first of 40 similar cars went into service in Boston. Work has begun on 70 such cars for Cleveland. The economies of the lightweight, quantity-produced equipments and the growing congestion of cities is expected to lead other cities to adopt rapid-transit systems operating on private rights-of-way or underground in the most congested areas, with feeders to them in the outlying areas.

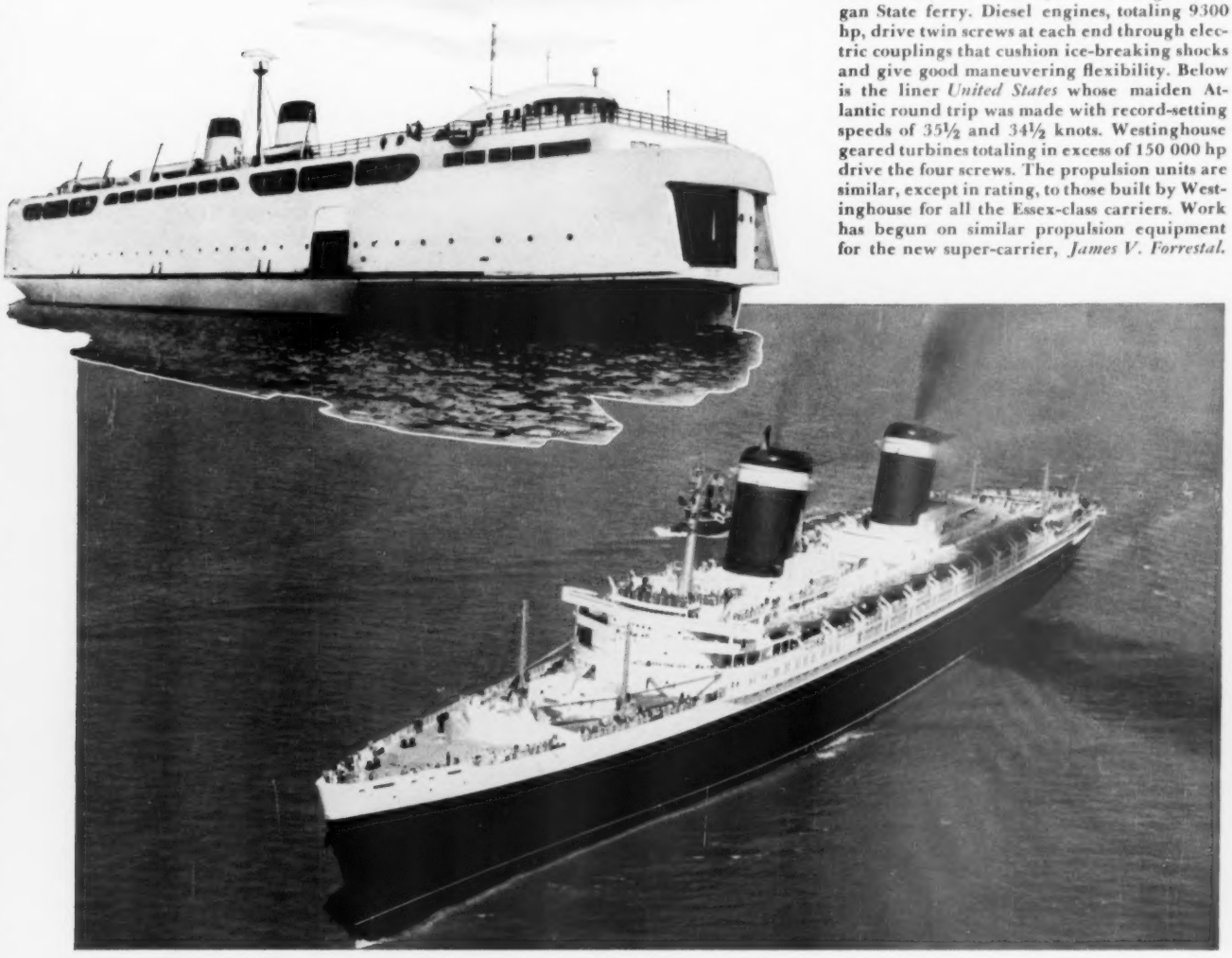
A Compact Load Tester for Diesel-Electric Locomotives

WITH THE old iron horse virtually deposed by the diesel-electric locomotive, a new family of tools is showing up in the locomotive shop. One is a means of loading the generator so that engine fuel racks, and other mechanical and electrical accessories can be adjusted for best performance. If a 2500-hp locomotive generator were loaded by the old cast-iron resistors, an array larger than the locomotive would be required. "Water-barrel" type rheostats have been used, but the thought of the headaches they entail in the form of water supply, corrosion, leakage, varying resistance, and general messiness makes any shop engineer wince.

A new, simple, compact load resistor is the answer to this problem. In outward appearance it resembles a metal coat locker and is not much bigger. It occupies about 3.5 by 4 feet of floor space and stands 9 feet high. The upper inside half consists of trays of trough-shaped strap resistance elements, made of a material akin to stainless steel and formed with a large area. In the bottom is a motor-driven blower that provides a powerful upward draft to carry the heat out the top. The blower motor needs no separate power supply. It takes power directly from the generator being tested.

This has another advantage. As the generator voltage rises, i.e., as its load increases, the motor automatically speeds up to increase the air supply and carry the extra heat away. The unit weighs only about 3500 pounds but can dissipate 2500 hp continuously.

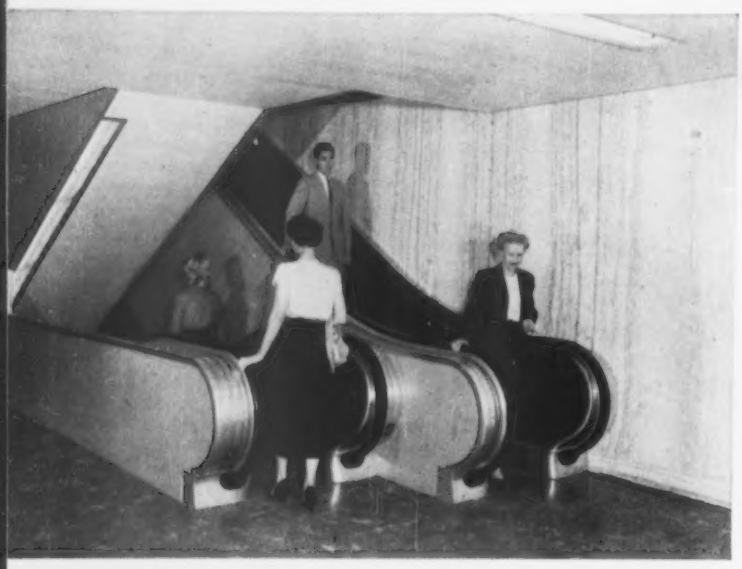
Marine



Left is the *Vacationland*, ice-breaking Michigan State ferry. Diesel engines, totaling 9300 hp, drive twin screws at each end through electric couplings that cushion ice-breaking shocks and give good maneuvering flexibility. Below is the liner *United States* whose maiden Atlantic round trip was made with record-setting speeds of 35½ and 34½ knots. Westinghouse geared turbines totaling in excess of 150 000 hp drive the four screws. The propulsion units are similar, except in rating, to those built by Westinghouse for all the Essex-class carriers. Work has begun on similar propulsion equipment for the new super-carrier, *James V. Forrestal.*

Breaking the Ice—In a Big Way

DURING WAR II nine ice breakers (named *"North Wind,"* *"East Wind,"* etc.) were built for the U. S. Coast Guard. These were 5040-ton vessels, each powered by two 5000-hp, d-c motors, the largest installed on any ship. These vessels established notable records of performance in arctic and antarctic regions, both during and since the war. Now a much larger, more powerful ice breaker is being built. It, too, will have two motors—but each will have more than twice the rating of the two "Wind" class motors. Each 10 500-hp motor will be 15 feet in diameter and will weigh 108 tons. Ten diesel-engine-driven generators will supply power to the motors, five being connected in parallel to each motor. The new vessel, yet unnamed, will be 41 feet longer and have a displacement of 3240 tons greater than its predecessors. This ice breaker, with 21 000 hp and its all-welded steel hull, will be able to break ice 20 feet thick.



This electric stairway runs at 120 fpm, instead of the usual 90.

Elevators

Progress in Vertical Transportation

LAST YEAR elevators took the final step to complete automaticity. Several banks of elevators in office buildings are now operating without either operators or dispatching attendants. Banks of elevators have been operated without attendants in the cab, of course, but they have required a dispatcher to select one of several modes of operation best suited to the traffic needs of the moment. This method has been used with attendant-operated Selectomatic system of elevator control.

The new system—Automatic Selectomatic—choses its own operation pattern, taking into account calls and stops, predominant direction of traffic flow, load (i.e., weight) in each car. The system, for example, automatically dispatches as many cars as necessary so that the average waiting time does not exceed a specified number of seconds. A car "knows" when it is loaded, by measuring weight, and refuses to accept any more calls until some passengers have been discharged, and takes several other traffic conditions into account.

All this automatic operation—of as many as six elevators in a bank—is accomplished by small electrical relays, of which a large number is required. For example, an Automatic Selectomatic system with automatic selection of traffic pattern for a typical four-car bank of elevators has 450 supervisory relays in addition to many electronic devices and 350 control relays.

Faster Stairways—In the United States the standard electric-stairway speed has been 90 feet per minute. The trend is to the use of electric stairways in single-tenant office buildings—even, in some cases, exclusively, no elevators being provided. For such service a higher speed is desirable, not only because the standard speed seems slow, but because of the need to handle more traffic. To this end, electric stairways have been developed to operate at 120 fpm. Experience with one office building depending entirely on high-speed stairways indicates that most office people prefer the higher speed.

Concentrated Freight-Elevator Loads—The use of industrial trucks hauling heavier and heavier loads has created a troublesome situation for freight elevators. A single truck can easily load a freight elevator to its rated capacity. If this truck is not in the center of the elevator platform, large unbalanced stresses are created in the car body and the uprights in the shaftway. Accidents may result.

Westinghouse engineers have urged that this situation be recognized by establishing a new industry-wide standard code of construction and elevator inspection. Such a code has been drawn and appears likely of adoption. Meanwhile, new designs for freight elevators for this service have been prepared. They provide additional "beef" in all parts of cab and shaftway structures to accept safely concentrated loads.

Lamps

Incandescent Lamps

WITH AUTOMOBILE traffic and high-speed night driving on the increase, the groups concerned with automotive regulations have asked for changes in head lamps. It is desired to project the passing beam farther out in front of the car without any increase in blinding effect to oncoming drivers, and with no more spill light immediately in front of the car to light up fog or rain particles. A difficult assignment!

An experimental *sealed-beam headlight* strikes at these objectives in four ways. A metal cap or shield in front of the filament cuts out all direct radiation from the bulb, which causes haze in front of the driver during fog or rain. The axis of the built-in reflector is tilted slightly to reduce the quantity of stray light thrown upward from the lens facets. The prisms on the lens have been rearranged to get sharper upward cut-off of the light. The two filaments have been relocated to reduce the angular spread between driving and passing beams. The throw (i.e., "hot spot") of the passing beam has been increased from 13 to 75 feet and that of the driving beam from 239 to 375 feet.

The voltages of the electrical system of some American

automobiles are doubling, going from 6–8 volts to 12–16. This is to accommodate the ignition needs of high-compression engines, and to help supply the growing electrical loads on the automobile, which will be further increased by air conditioning.

The doubled voltage would seem to be a good deal all around: larger capacity from generators and motors of given size, reduced losses, and so on. But to the lamp designer it is a pain in the neck. Lamp filaments, for the same output, become smaller and longer, and hence less able to stand the vibration. The final lamps for this service have not yet emerged from the laboratory, although tests on models produced to date indicate that the more difficult requirements will be met.

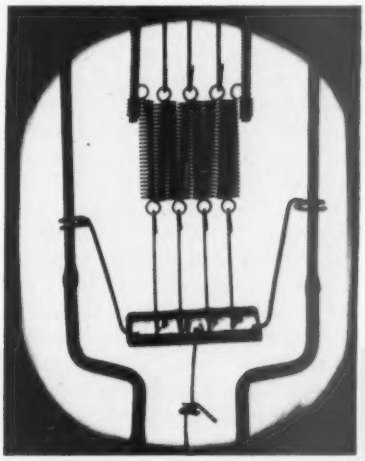
Helicopter Lamps—For a human being, an acceleration of 6 or 8 g's is high; 10 or 12 the limit of endurance. An incandescent lamp for one unusual application must get along nicely with angular accelerations of 200 g's. The job: lighting the tips of helicopter blades. These blades swing in a 48-foot circle at 270 rpm (i.e., tip speed of nearly 8 miles per minute). Sort of a perpetual crack-the-whip. That a lamp can be built to take it is more surprising when it is realized that the tungsten filament is operating not far below the softening point. The filament developed for this not-so-merry-go-round service is in three sections forming three sides of a rectangle, with each corner rigidly braced.

Lamp Bases—Large tonnages of brass are used annually for lamp bases. The copper situation being what it is, a switch to aluminum would be desirable. Because of problems of soldering, and the temperatures at which glass must be sealed into the base, this is not as easy as it might seem. So far, aluminum-basing techniques have been worked out for the common medium-screw base. The quantity of copper Westinghouse can save when this move is complete is considerable—in the neighborhood of 1000 tons per year.

A new solution has been found to that old troublesome matter of sealing high-wattage lamps (i.e., 300 to 2000 watts) into their bases. Because of heat, the conventional Bakelite cement weakens and eventually loses its grip on the metal and the glass. One solution used for some time with fair success was a so-called mechanical base by which the glass and brass are held together by suitable mating indentations. But engineers never felt comfortable with this system. Then came silicone cement. It can withstand the temperatures. However, it is thermosetting and doesn't harden in the few seconds that can be allowed on practical lamp-basing machines. A combination of Bakelite and silicone cement does the trick. The older cement is applied first, farther down in the base; silicone is applied to the outer threads. The conventional cement hardens almost instantly, forming the necessary seal that is more than adequate until the silicone cures—which it does quickly when the lamp is burned.

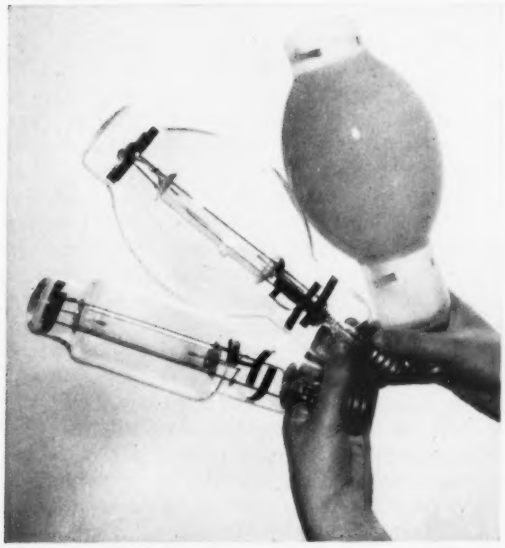
More Light from Same Watts for Home Movies

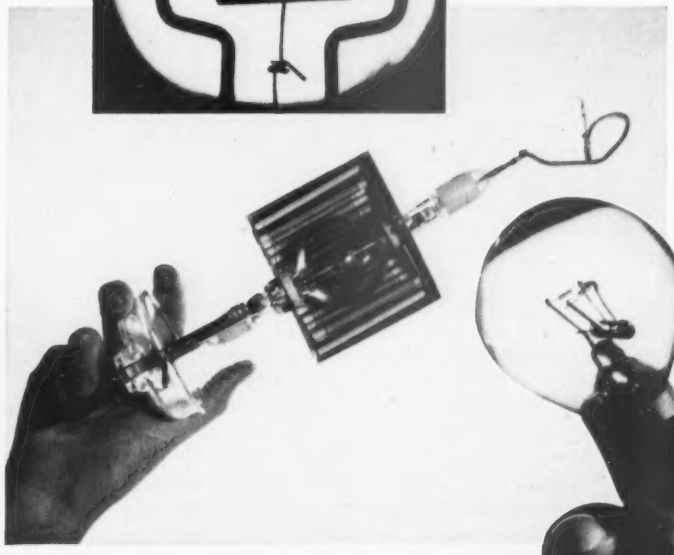
The home-movie fan is forever seeking greater brilliance for his pictures. Projection-lamp designers have given him a big assist toward his objective. Heretofore, filaments were hand formed and assembled. But the work of even the most careful operators is not without variation, which means an appreciable spacing (actually only 0.038 inch) between the planes of the two rows of filaments. A machine has been developed for forming the filaments. Because they are much more accurately formed, the space that must be allowed between rows can be reduced—in fact by 15 percent. Also, the distance between individual coils in each row can be reduced, by 20 percent. By virtue of an improvement in the metallurgy of tungsten wire, the coils can be wound tighter.



Left: close-up of the filament of the new home-movie projection lamp. Lower left: the old, the new mercury lamps, and the new 400-watt fluorescent-mercury lamp, respectively. Below: short-arc mercury lamp with heater. Inset: lamp for helicopter wing tips.

and Lighting





Both flush-type fluorescent units and low-brightness luminescent panels are used effectively in this well-lighted executive office.

For Better-Lighted Offices

IN STEP with the trend to more light in modern offices and for more attention to appearance of both new and modernized offices, a family of greatly improved fluorescent-lamp fixtures has been provided. These are arranged to meet the general situations found in modern, low-ceiling offices for mounting within the ceiling or for mounting against the ceiling.

The effect is pleasing when units can be buried within the ceiling, with nothing projecting below. For such purposes, the depth of the fixture must be the least possible. The new one measures only $6\frac{3}{4}$ inches deep. The bottom is absolutely flush with the ceiling (most so-called flush units project by a fraction of an inch). The reflector on this and other office units has undergone an analysis in the photometric laboratory, with a consequent change in shape and placement of lamps that increases the useful light by 15 percent. The "egg-crate" louver is made much more rigid by a new resistance-welding technique that spot welds the edges of its interlocking sections. There may be as many as 620 spot welds in a single louver. With an eye to the serviceman's problem, each lamp holder, starter block, or ballast can be removed without interfering with other connecting units. New housing seals get rid of cracks by which stray streaks of light can escape.

Most of these features are carried over to the units mounted against the ceiling. By careful design, the ceiling-mounted unit is but $3\frac{5}{16}$ inches deep, which is important in low-height offices with ceilings that can't take recessed units.

Mercury Lamps

PARENTS oftentimes learn from their children. Something of this sort has happened in the mercury-lamp family. The gain is a new shape of the outer bulb leading to lamps better suited to quantity production. To explain this requires telling a bit of mercury-family history.

Bulb Shape—General-purpose mercury lamps consist of an arc contained in a tube of quartz or high-temperature glass, and the whole surrounded by a second cylinder of glass that protects the inner lamp parts and absorbs the ultraviolet radiation. A few years ago the outer glass wall was made of Pyrex-type glass. But the life of these lamps was unsatisfactory. Research proved that the outer glass wall gave off a water vapor that was dissociated by the heat and ultraviolet radiation into oxygen and hydrogen. The hydrogen then proceeds to raise hob with the quartz chamber and the arc space. Hydrogen molecules pass through quartz almost as readily as marbles through a tennis net. The arc-chamber gas soon becomes contaminated with hydrogen, which makes the lamp hard to start. Hydrogen affects the quartz itself, making it milky and altering its color quality.

It was believed that the answer to the problem was to use a harder glass for the outer bulb, even harder than Pyrex. This change was made and lamp life was greatly improved. Mercury lamps have been made this way now for several years and have been most satisfactory.

Then, about two years ago, the fluorescent-mercury (color-corrected) lamp was introduced—a mercury lamp that produces golden-white light. The arc tube remained the same as in the straight mercury lamps of the same rating. But the outer bulb was bulged out in the center so that the phosphors coated on its inner surface, being a little farther away from the arc tube, don't get too hot. The fact that this outer glass temperature is reduced permits use of lime glass, which can be formed by machine instead of manually blown, and which is easier to work with gas flames. Time later made evident that this lime-glass lamp also has long life, equal or superior to that of the super-hard glass tube. This led to the conclusion that the early difficulty with hydrogen emission from the outer enclosure is not a function of hardness of the glass but a characteristic of the particular semi-hard glass used.

Perhaps the regular mercury lamps could be made with lime-glass outer enclosures bulged like those for the phosphor-lined tubes. The advantages are those of machine versus manual production. But it was feared that the new, larger bulb would not be as good optically in the fixtures designed for the smaller, straight-sided lamps and used in such large numbers, particularly in street lamps. Photometric tests proved them at least as good, perhaps better. Hence, quartz-mercury lamps—in the 250-, 400-, and 1000-watt rating—have the shape developed out of necessity for the color-corrected lamp. The result is general benefit both to manufacturer and user.

The improvement has also been extended to the glass arc-tube mercury lamp. This lamp, the original commercial high-pressure mercury lamp, standardized in 1934, is still used in quantity, in spite of its lower efficiency, because of the lower cost possible by using glass instead of quartz for the arc tube. Now the outer enclosure of this lamp is made of lime glass.

Seals—Three years ago a novel solution was found to the problem of a seal for mercury lamps. It was then applied to the 400-watt rating. The problem is how to seal the quartz or hard-glass arc tube to the tungsten lead-in wire and accommodate for the large difference in thermal expansion between them. The old method had been to build a graded seal between the quartz, say, and the wire, consisting of several glasses of different expansion coefficient. This graded seal was difficult to make at all; impossible to make consistently. Inevitable slight variations in manufacturing resulted in strains in the seal that led some lamps to premature failure.

This difficulty has been solved by a ribbon seal. The lead-in wire is made of molybdenum ribbon only 0.0006 inch thick. This is sealed directly into the quartz with no graded seals. Although the thermal expansion of moly and quartz differ,

the moly ribbon is so thin it yields under pressure of expansion without destroying the seal.

This ribbon seal has approximately doubled the rated lamp life and has reduced the nuisance of early failures. The performance has been so good on the 400-watt lamp that ribbon molybdenum seals have recently been extended to the 250- and 1000-watt lamps.

Mercury Lamps for 460 Volts—Designers of mercury lamps are taking advantage of the growing availability in factories of higher distribution voltages. A 1000-watt mercury lamp (AH15) is designed for use on 460 volts. With an arc voltage of 265 volts instead of 135 volts, the ballast can be much smaller and less expensive. A fluorescent version of this high-voltage lamp (BH15) has also been developed.

Reflector-Type Mercury Lamps—The mercury lamp has also recently been developed with a built-in reflector. It is a 400-watt lamp 7⅛ inches in diameter, and is built with two bulb contours to give a choice of two light-beam distributions. Reflector lamps are needed in factories with exceptionally dirty atmospheres, where it is necessary to minimize light losses and reduce fixture cleaning costs. In this unit the arc tube is supported at both ends—at the outer end as well as the lead-in end. This provides rigidity and permanence of the optical properties of the lamp.

For Better Factory Lighting

EVEN TWO or three years ago a factory was considered well lighted if a high level of illumination was provided on the working surfaces. But not now. The trend is to maintain more nearly uniform brightnesses throughout the visual field. In other words, no bright areas adjacent to dark ones. The ceiling can no longer be left an area of darkness behind the light sources. Some light must be allowed to penetrate upwards from the reflectors.

Furthering this trend is a new family of fluorescent-lamp fixtures for factories designed to allow one fourth of the total light output to be distributed upward. Also, with the ceiling brighter, the outside of the fixture should be lighter so as not to offer a dark area against a light background. These new units, accordingly, are enameled white on the outside as well as on the inside.

Ventilated Lighting Fixtures—If the conventional highbay incandescent or mercury lighting unit in a factory is not washed at intervals, the output from the reflector may drop by half because of the dirt that the circulating air currents cause to precipitate on the reflector. With a new fixture, arranged with air outlets near the neck of the lamp, the decline in light output even in very dirty environments and with no maintenance does not exceed 20 percent. The point is, of course, that dirt-laden air can pass up through the fixture and on outside instead of moving in closed eddies inside the housing.

The shape and placement of the holes are important. They must be large, else dirt will collect on the surface between them. They must not allow water to drip into the lamp and they must be placed as low in the neck of the fixture as possible so the socket will not be swept by a blast of hot air and thus heated instead of cooled. These qualifications are met in this new fixture by making it in two pieces of spun aluminum, one for the reflector, the other to surround the lamp socket. They are assembled together with an open "vent" between them. This vent extends, at an oblique angle downward, for the full circumference of the fixture except at the four points of attachment. The two-piece reflector is stronger than that spun of one piece because no openings are punched out and because it avoids the thin-metal areas that result in spinning a unit with a small diameter neck for the receptacle and a wide flare for the reflector.

Color-Corrected Mercury—Another trend in factory lighting is to improve color quality of light as well as its brightness distribution. The color-corrected mercury lamp is helping do this without the expense and complexity of supplemental incandescent lamps. To take advantage of the recently announced 1000-watt color-corrected mercury, a large spun-aluminum reflector has been devised. It incorporates the features of ventilation and low maintenance worked out for other industrial fixtures. It has good efficiency in spite of the "football" size bulb. About 78 percent of the light created by the lamp gets out of the reflector to be utilized in the working areas.

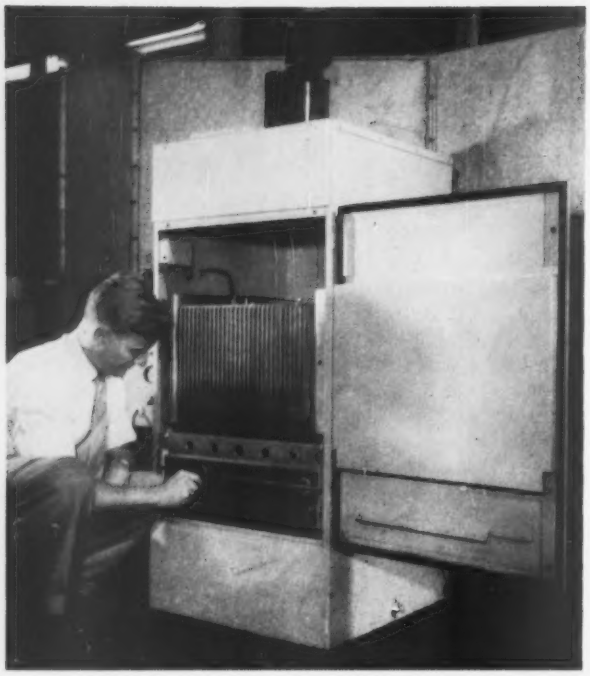
Refrigeration and Air Cleaning

Store Air Conditioners Meet Many Space Requirements

AIR-CONDITIONING units for stores have achieved a new order of magnitude in flexibility to meet different space and air inlet and outlet conditions. Store air conditioners must tuck away in the smallest and least-valuable spot available. This new flexibility is accomplished by building the unit something like a sectional bookcase. The fan or outlet section is square. It can be placed on top of the compressor section, lying on either side, or with outlet upwards. This gives a choice of three outlet-air directions. Stacked in this fashion, the conditioner of 10-ton rating occupies 32 by 61 inches of floor space and stands 91 inches high.

Or, if vertical space is the more limited, the outlet section can be mounted on the side of the compressor section, and again turned to direct the cool air upward, downward, or horizontally. The unit then stands 60 inches high. Ten combinations of air inlet and outlet directions can be had.

These new store air-conditioning units are developed in two sizes—10-ton and 15-ton (MU 101 and 151). Both have two compressors, to provide economical half-load operation. Both units are self-contained, requiring only electrical and water connections.

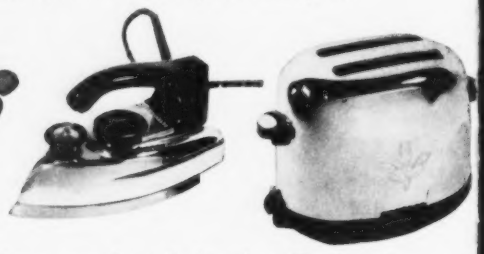


The capacity of high-speed cutting machines is rising steadily. In some cases the capacity of the standard 600-cfm Precipitron units used to capture the oil mist from the cutting oil is inadequate. A new unit of 1200-cfm has been developed for this purpose. Both it and the 600-cfm models have new improvements that add to flexibility of operation, such as mounting positions, and dampers to control the speed of oil-mist-laden air through the unit.

Water-Cooler Drain Water Is Put to Work

A LOT OF useful "cold" literally goes down the drain from water coolers. In normal use more chilled water runs directly into the sewer than is drunk. Engineers are putting this cold water to work. First they are using it to precool the incoming water, thus reducing the load on the compressor. This has been done before. But there is still some "cold" left in this waste water even after chilling the incoming water by ten degrees or so. The waste water temperature may still be only 60 or 70 degrees F. Now, before allowing this waste water to drop finally out of reach, it is made to flow over the condenser heat exchanger, which may be 120 degrees, to provide the cooling that has previously required a fan. This now makes possible a naturally air-cooled water cooler with even greater capacity than the previous fan-cooled unit. It also makes possible an air-cooled static-condenser water cooler for use in hazardous atmospheres, as in refineries, flour mills, etc.

Home Appliances



Help with the Homework

WOMAN'S WORK, so goes the adage, is never done. With labor-saving electrical devices now in such general use, that statement is open to question. However, the work of those who design such appliances is never done. This consists of finding ways of creating devices that are simpler to use, provide new functions, do a better job, are better looking, need less service, and that use less critical materials.

The Dryer—The running mate to the Laundromat washer, the dryer, has a pair of interesting new features. One combines appealing novelty with utility. The dryer announces its completion of the task with the tune "How Dry I Am"! The creators of the dryer have sensed that some audible indication of completion of the drying cycle is needed, so that the housewife can meanwhile proceed with other duties. The obvious solution was a bell. "But," one designer reasoned, "why be prosaic? Let's use a chime."

Sounded like a good idea, and a simple one. But its execution was not as simple as expected. It would seem that musical-instrument makers or perhaps manufacturers of children's chimes could easily provide the desired device. But not so. For one thing, available simple chimes aren't loud enough, with the dryer in the basement, to be audible in, say, a second-floor bedroom. The chime had to be low in cost. Anyway, laundry-equipment engineers found themselves engaged first in studying the principles of chime devices and finally creating from scratch a chime to fit their special needs. As contrived, it is a plastic housing with precisely dimensioned molded resonators, a tiny gear motor, a cam, five hammers, and five note bars tuned to within one-half note. The unit, stashed away in the dryer, adds a new and pleasant note to washday.

The dryer also has a new control element. Many of the newer fabrics call for a very short drying time. To give the housewife greater control of drying, the control is arranged so that she can select as little as five minutes drying time, and even that without the application of heat if she wishes—just tumbling in a draft of air.

The Steam Iron—The clothes washed and dried, there is still the ironing to be done. And this task is being simplified by the steam iron that has been rising astronomically in favor. A new one, introduced last year, embodies several improvements. Because it uses the open handle (i.e., the handle is attached only at the heel) the water-filling mechanism can be simple and more accessible. The iron can be filled in the ironing position (i.e., not turned up on the heel rest). An air trap provides an automatic control of filling so that as the water expands on heating, it does not overflow. Baffles prevent water splashing out onto the garments in the vigorous motion of ironing. Steam outlets in the base provide an uncommonly large area for steam to penetrate the fabric. The needle valve that permits water to drip into the flash-type boiler is self-cleaning. Each time the control is changed to dry ironing or to the filling position, a plunger passes all the way through the opening to remove any impediment.

Thermostats—The direct approach is usually the best approach. Thermostat engineers are applying this philosophy with benefit. The time-honored way of specifying thermostat material from manufacturers of bimetal has been to name its width, thickness, and the alloys used. But, even so specified, there has been considerable variation in the range of temperatures at which the contacts act. Actually what is desired is uniformity in the deflection per degree of temperature change.

Now thermostat designers ask the bimetal maker to provide a material with a given amount of deflection over the desired range and let the thickness go hang. That is simple for bimetal producers to do and results in thermostats that are more accurate, with fewer rejects, and that save critical materials.

Electric Range—What can one do to improve the pots and pans drawer of an electric range? Nothing—one is prone to say. It is but a simple bin of light-gauge metal, on rollers. Just the same it has been done. Now the drawer can be pushed shut—even with the foot if mamma is in a hurry—without waking the baby. A rubber bumper now softens the last fraction of an inch of travel, but, more than that, a layer of glass wool between the porcelain front and the front wall of the drawer keeps the thin metal front panel from behaving like a sounding board.

Toaster—With the new toaster you get toast in 90 seconds flat—first slice, last slice, light, or dark. This is considerably less than is the case with the average toaster. A new control element operates to control the heat alone. Time is not variable. The thermostat does this by cutting the heating element in and out of the circuit just right to produce the desired brownness in the time of 90 seconds always measured out by the timer.

For Better Viewing and Listening

TELEVISION sets now adjust their own picture brightness automatically in accordance with the level of room illumination. If the room is comparatively dark, the screen brightness should be low, otherwise there will be eyestrain in looking at a bright picture against a dark background. On the other hand, if the room lighting is fairly high, the maximum screen brightness is required to keep the picture from being washed out. A tiny photoelectric tube concealed behind a translucent panel takes care of this situation.

Another aid to eye comfort for television viewers came by way of the picture tube itself. The tube face now has the curve of a vertical cylinder instead of a sphere. For structural reasons (tubes are large, evacuated vessels and must be able to withstand atmospheric pressures) picture tubes are curved, and until about a year ago this curve was that of a sphere of large radius. But tube makers have learned how to build strength into tubes curved in only one direction. Westinghouse helped pioneer the application of these tubes. The cylindrical tube greatly reduces the distortion of vertical forms (such as a standing person) and causes much less reflection of overhead bright objects into the viewers' eyes.

When television receivers were in their formative stages there were two possible means of focusing the beam in the picture tube: electromagnetic and electrostatic. By and large the industry elected to follow the electromagnetic road, probably because the tubes are somewhat easier to build and cheaper. All went well until the cobalt shortage loomed—the permanent magnets for an average-size tube weigh a couple of pounds, much of it cobalt. So tube and set designers went and took another look at electrostatic focusing, and what they saw they liked. Westinghouse has now converted all television-set designs to this type of focusing. Not only are sizable amounts of scarce metals saved (and set weight slightly reduced) but some operational gains have resulted. For example, with the electrostatic system a change in line voltage does not affect picture clarity, which is the case with electromagnetic focusing. Also focus is sharper across the tube face.

About a year and a half ago Westinghouse engineers decided to design television sets that could be converted with the maximum ease for use on uhf (ultra-high-frequency) channels as they become available by action of the FCC. Accordingly, two types of uhf tuners were designed and all Westinghouse television sets (except the economy models) built during 1952 were designed to accept either tuner. One is a fixed-channel tuner. It is a plug-in device, and receptacles are provided in each television set for two of these. In very few locations will more than two uhf channels be available. This plug-in tuner is extremely compact; it is not much larger than a penny match box. To use it, the set owner simply plugs it into the receptacle provided, and connects his uhf antenna to an indicated terminal. The television chassis does not have to be removed from the cabinet; no serviceman need be called in. Even the tuning dials on all 1952 sets were equipped with two more positions in anticipation of uhf-channel assignments.

One of the oldest of appliances is still the most popular—the electric hot plate. The new one is both more attractive and more efficient. The two heating units are enclosed in titanium steel with a black-oxide coating that increases the heating efficiency.

At right: The young lady holds the chime that, mounted in the dryer, announces the end of the drying cycle.

New Knowledge

Working on the Mystery of Phosphors

LAMP-RESEARCH engineers are interested in electroluminescence only abstractly as an illuminant—for that possibility at present appears remote. However, they are much interested in it as a route to an understanding of the phenomenon of phosphor luminescence. Hence the laboratory study of electroluminescence goes on steadily.

Several new things about it have been learned lately. For example, certain phosphors, particularly of the sulfide type, which are photoluminescent (i.e., the property of phosphors in fluorescent lamps) but have been considered non-electroluminescent, are found to electroluminesce in a vacuum. Also it has been discovered that this property for these materials is destroyed rather than enhanced when they are mixed with dielectric oils and plastics as is done with the common electroluminescent powders. These and related facts have led to the hypothesis that vacuum-sensitized electroluminescence is a surface effect involving gas adsorption on the phosphor crystal surfaces.

There is not much comfort in all this for anyone anxious to see commercial electroluminescent light sources, but there is a great deal of value in it for research men who are probing the secrets of phosphors.

Photoflash Consistency

IT IS exasperating to have a photoflash fail to fire, or—unknown to the photographer—to fire late. Worse still is to have a photoflash lamp shatter when fired. This latter is rare, but even once is too often.

A lamp research investigation has shown that many factors affect photoflash performance. Primarily this concerned the foil-less (SM) type of lamps used with the inexpensive cameras having simple shutter synchronization.

Most important is battery condition. With new batteries—dry cells are ordinarily used—peak currents up to about eight amperes are obtained, which brings the light intensity to a peak in about five milliseconds after voltage has been applied to the lamps. When batteries are old the current can drop to about an ampere with peak light intensity occurring between 10 and 20 milliseconds. With currents of one-half ampere the lamps don't fire at all.

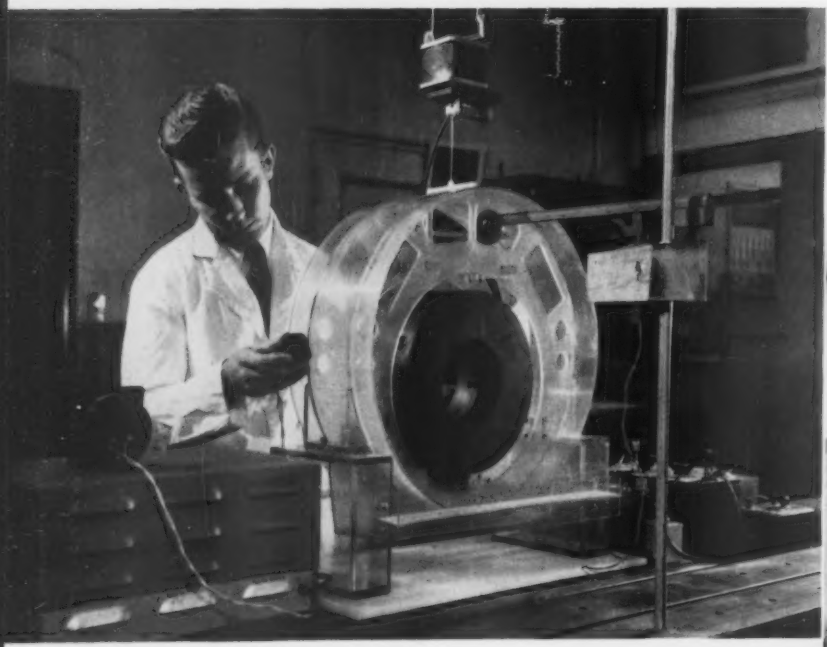
Also the bearing of various factors under the control of the lamp manufacturer has been ascertained. These include the size (i.e., amount) of combustible beads, the age of the material when applied, the amount of water vapor present, and the presence of inert gases mixed with the oxygen.

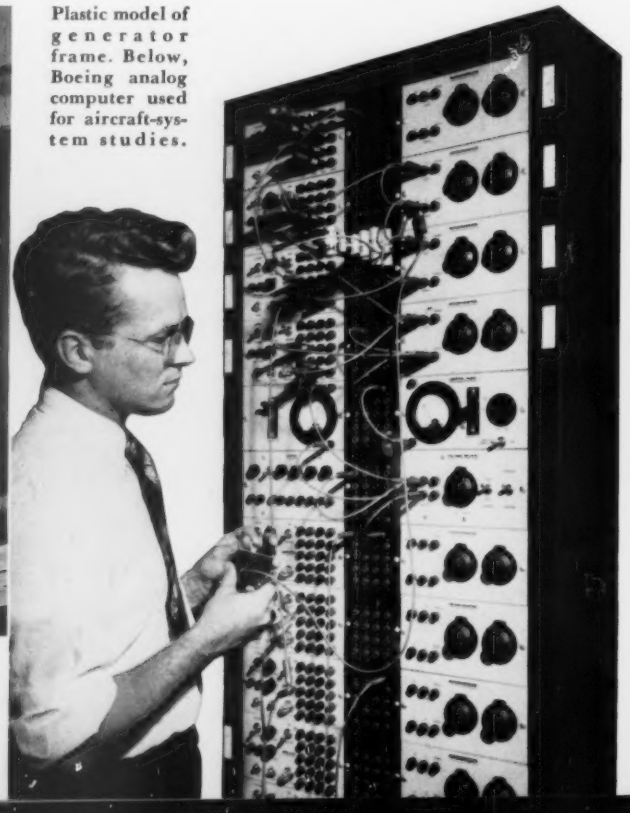
Photoflash lamps, it becomes evident, are not simple things. However, the investigation did result in the definition of process controls that produce more uniform lamps, lamps that the photographer can depend on for good picture results, and that are completely safe when used with proper equipment.

Plastic Models Aid Vibration Analysis

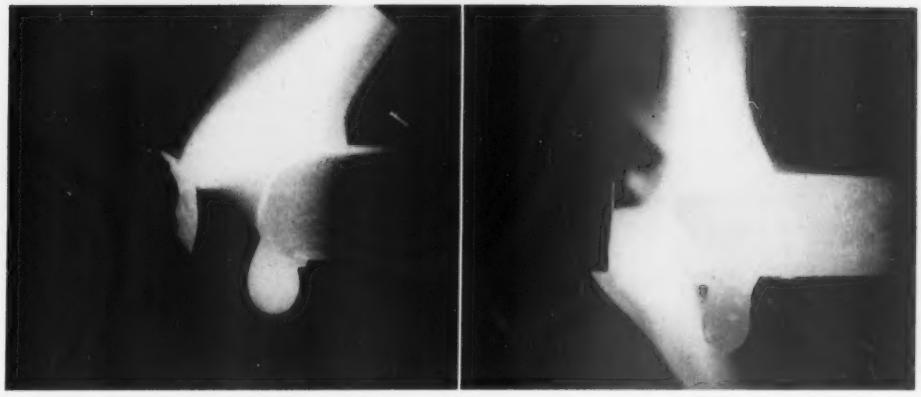
PLASTIC models of machines have been used to study the strains and deflections resulting from static loads. Now these inexpensive translucent miniatures are being used for dynamic investigations of vibration.

An important application of dynamic-model analysis is the design of large generator frames where description of the structure for mathematical computation, even by a calculating machine, is hopelessly complex and uncertain. The





Plastic model of generator frame. Below, Boeing analog computer used for aircraft-system studies.



The trend is to use electric-arc casting of high-temperature metals, such as titanium and molybdenum, in ingot form. A research program is under way to determine what happens at the electrodes and to find explanations for unexplained phenomena. For example, in a d-c arc with massive, consumable electrodes the higher the melting point of the metal the greater the tendency for the anode to melt first. Answers to such matters are expected to lead to improved arc-casting techniques. In both illustrations the anode is the right electrode. In the left view, both electrodes are molybdenum. In the right view, the cathode is moly; the anode is tungsten, which has a higher melting point than moly.

plastic model is constructed geometrically similar to the prototype structure or structure section, and usually in greatly reduced size. Alternating forces are applied to the model over a range of frequencies of interest by an electromagnetic driver not unlike the driving element of a radio "loud-speaker." A typical resonance curve is obtained that is readily interpreted for the prototype by accounting for the differences in the mechanical properties of the model and prototype materials. The vibration peaks can then be located safely away from known excitation frequencies, which in a 3600-rpm, 2-pole machine are 60 and 120 cycles per second.

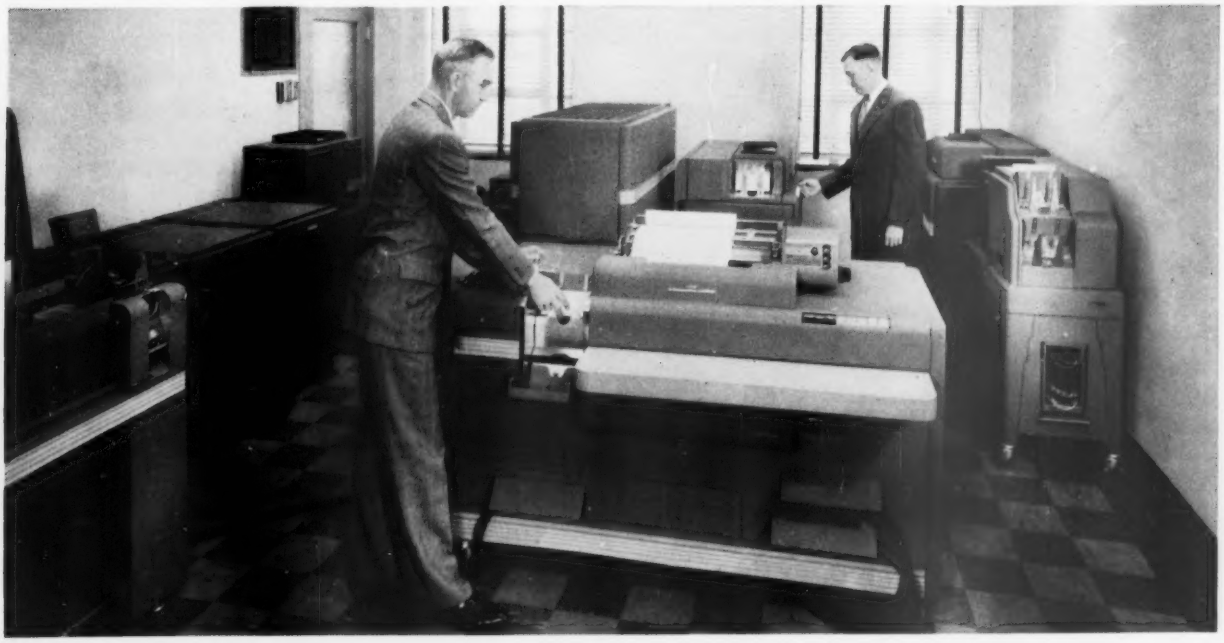
Plastic models are inexpensive and are easily modified to take account of proposed design changes in the actual machine. The mechanical properties of the material are such that even with models of reduced size the frequencies of interest are low where vibration excitation and measurement are convenient. However, these properties of plastics upon which proper interpretation of test results depend are influenced by temperature, frequency of vibration, and to a lesser extent, humidity. Thus, these properties must be carefully evaluated over the range encountered in model testing.

Computer Developments

ENGINEERS feel as naked without slide rules and desk calculators as girls do without lipstick. Many engineers have come to find the large analog and digital computers equally essential to their everyday operations.

This trend is reflected throughout the engineering departments at Westinghouse by the growing use of special- and general-purpose computers. Analog computers have been or are being installed to assist in the design of industrial motors and their control, of fractional horsepower motors, of air-

Computers



craft electrical-control systems, of nuclear-plant control, of special apparatus for military aircraft, and in the Research Laboratories.

Since the installation of the Card Program Calculator (a general-purpose digital computer) at East Pittsburgh last April, some considerable steps have been taken in extending digital computing into the fields of design and application of power apparatus. Numbers and instructions are fed into the machine in the form of punched cards—and the CPC cranks out answers that would take engineers months, years, or even lifetimes to calculate by longhand methods.

One such job was a gas-flame problem, involved in the research in gas-turbine design. It was necessary to determine by numerical integration a coefficient to be used in the equation expressing burning velocity of the flame.

The CPC has also been instrumental in the thermodynamic design of gas turbines and wind-tunnel compressors. In the case of the gas turbine, the blade angles are determined so that each set of blades will do the proper amount of work desired. These calculations must satisfy both the conservation of momentum and the conservation of energy laws, involving a tedious cut-and-try procedure. But once the process is coded for the machine, variations can be handled readily and economically. The compressor calculations involve stage-matching calculations; results from individually tested stages are combined to determine the performance of the complete compressor.

Natural frequencies are determined for a variety of systems, ranging from small individual turbine blades of a few inches in length to the complete turbine generator. As a result of these studies, equipment is designed that will not be in danger of literally "shaking itself apart" at resonant frequencies.

These represent a few of the problems that the newly formed digital computing group in the Analytical Section is handling. For the Analytical Section, this represents a rather major step in computing.

Studies of Aircraft Electrical Systems

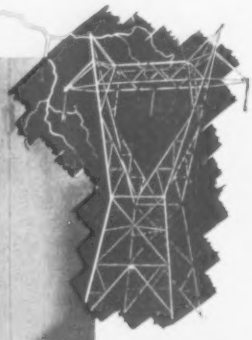
SOLUTIONS to complicated aircraft regulating system problems are greatly expedited by the new Boeing analog computer. It can solve up to sixth-order differential equations and is being used extensively to study factors that affect stability of regulators, the influence of variables in the performance of multiple-unit power systems, as well as for mechanical problems such as those of vibration dampers.

Making Transients Stand Still

ONE OF the problems in studying an electrical transient wave is just that—it is transient. However, by means of a device known as a Synchronograph, a transient simulating a lightning wave is repeated so rapidly that it looks like a steady-state phenomenon and hence can be studied at leisure.

This new system is being used to study surge-voltage distribution and attenuation in connection with lightning arrester application problems. A repetitive surge generator supplies the simulated lightning wave to the system being measured. The resulting wave form is measured at the desired point in the system; by using a high repetition rate (60 times a second), the wave form appears as a steady-state trace on the oscillograph. The system is synchronized from a common 60-cycle system.

The Synchronograph has been very useful for studying surge protection and arrester application problems on systems where there is no corona or where corona effects can be neglected, such as short lengths of transmission line, power cables, generators, transformers, substations and line traps.



A special high-energy surge-comparison tester, developed primarily to check quality of large coils used in generators.

Measuring Odorout's Ozone

OZONE in small, "natural" amounts kills odors and gives freshness to the air. Ozone, which is "heavy" oxygen (O_3), is created naturally by sunlight and is noticeably present after severe lightning storms. Ozone is short lived. It is such a powerful oxidizing agent that it quickly combines with other substances. Hence ozone is almost completely absent inside buildings. To provide a source of low-concentration ozone the Odorout lamp was introduced about a year ago. It has proved very popular as a means of eliminating household odors.

A research program has been underway to determine the exact amount of ozone produced by this lamp and the extent to which ozone can be built up in, say, an average room. It is known that ozone in large concentrations is toxic. The research has proved that the maximum concentration obtainable with the lamp is less than is present in a New Jersey meadow on a summer day. The ozone is about 2.5 parts per hundred million by weight, so small that extraordinary techniques were required to measure it. Also established was the process by which ozone destroys odors.

Nuclear Energy

Reactor Materials Problems

WELL UP in the list of hundreds of positive additions to engineering know-how, arising out of the intensive effort to produce a military nuclear power plant, are new materials and a great deal of new knowledge about older materials. Zirconium is one of these. In fact one of the most spectacular of all materials stories is that of zirconium. Four years ago it was even scarcer than metallic uranium at the time the atom-bomb project was begun. All the metallic ductile zirconium in the world could be contained in a small box. When sold it brought a price almost as much as gold. The Westinghouse Atomic Power Division has produced several thousand pounds per month and the cost is only a tenth of the previous figure.

Why the sudden interest in zirconium? It is to have a basic place in the nuclear reactor for the submarine. The nuclear-energy field is a strange new world that necessitates many ideas. We think of iron, steel, aluminum, and other metals as materials of great strength and permanence, and use them for engineering structures. But as structural materials for enclosing the uranium elements, they won't do at all. This fact sent chemists, physicists, and metallurgists scurrying to find a suitable material. The best one—in fact almost the only one—turned out to be little-known zirconium. Not only have ways been found to make it in quantity, at reasonable cost, and in desired purities, but also its complete spectrum of physical and chemical properties has been determined, as well as ways to roll, form, and weld it.

The nature of literally hundreds of materials problems is suggested by two specific cases. One is the matter of metal-to-metal wear. In many places in the reactor, metal moves in contact with metal, the only lubricant being air or hot water. A large amount of research has been devoted to finding the best combinations of metals to operate under these conditions.

Another problem is that of contact corrosion. Different metals in contact corrode—perhaps slowly—but corrode they will. If these parts are intended to move, perhaps after long periods of inactivity, the corrosion product at the contact surface may cause the component to freeze. Research has been directed to determining the proper metals for such situations or to developing proper practices for operating such elements at intervals.

Counting Fissions and Neutrons

THE SPECTRUM of energy output of a nuclear-power reactor may span a total of ten decades. That is, the power level can vary over a range of ten billion to one. And this full range of power must, obviously, be accurately monitored by radiation-measuring instruments. No single device in existence comes even close to covering a scale of such breadth. Of necessity, instruments of different sensitivities, overlapping in range, must be used to watch the uranium at work. A trio of types of radiation detectors are now at hand: fission counters, ion chambers, and proportional counters. They are beautiful in their simplicity. Externally each appears to be but a sealed cylindrical tube a couple of inches in diameter and eight inches to about two feet long.

For measuring the medium ranges of reactor power, we have the *fission counter*. Its approach to the problem of determining the rate at which fission is occurring within the reactor is direct. It contains a central stem plated with fissionable uranium (U^{235}). When exposed to the same neutron host at work within the reactor itself, its uranium nuclei, when struck by neutrons, are likewise disintegrated, giving off the nucleus fragments plus energy. The fragments ionize some of the gas within the counter. The ionization is easily measured electrically and in magnitude bears a direct relationship to the total number of neutrons in the reactor. An important mechanical feature is its use of pressure fits and welding of the separate parts to maintain the absolute tightness essential to prevent spurious ionization from leaking in, or interior ionization from leaking out uncounted.

Covering the upper region of power levels is the compensated *ion chamber*. It obtains its wide range of neutron detection by having a reduced gamma-ray sensitivity. It is really two chambers, one within the other. The outer chamber is surfaced with a layer of boron, which, when hit by a neutron, throws off ionizing particles. The inner chamber contains no boron. Gamma radiation causes ionization in both chambers, neutrons in only the boron-lined chamber. Hence it is possible, electronically, to subtract one from the other to get a measure of the neutron level. An essential fact in obtaining this larger range is that the ionization caused by gamma rays and collected from the two chambers be identical. This can be done by making the chambers of identical size, an extremely difficult mechanical feat when one considers that the device must have weld-tight joints—no bushings, no protruding shafts. A way has been found to do it electrically.

Finally, filling in the bottom three decades of power levels, is the *proportional counter*. It is the most sensitive of the three, and is the simplest in physical form. It resembles and operates on much the same principle as the Geiger counter. It is a tube with a central wire electrode, but the space is filled with boron trifluoride, a gas, which is especially sensitive to neutron bombardment.

This trio of radiation-sensitive devices has a growing field of usefulness for control and protection wherever uranium piles are used.

High-Speed "Brains" for High-Speed Planes

High-Speed "Brains" for High-Speed Planes

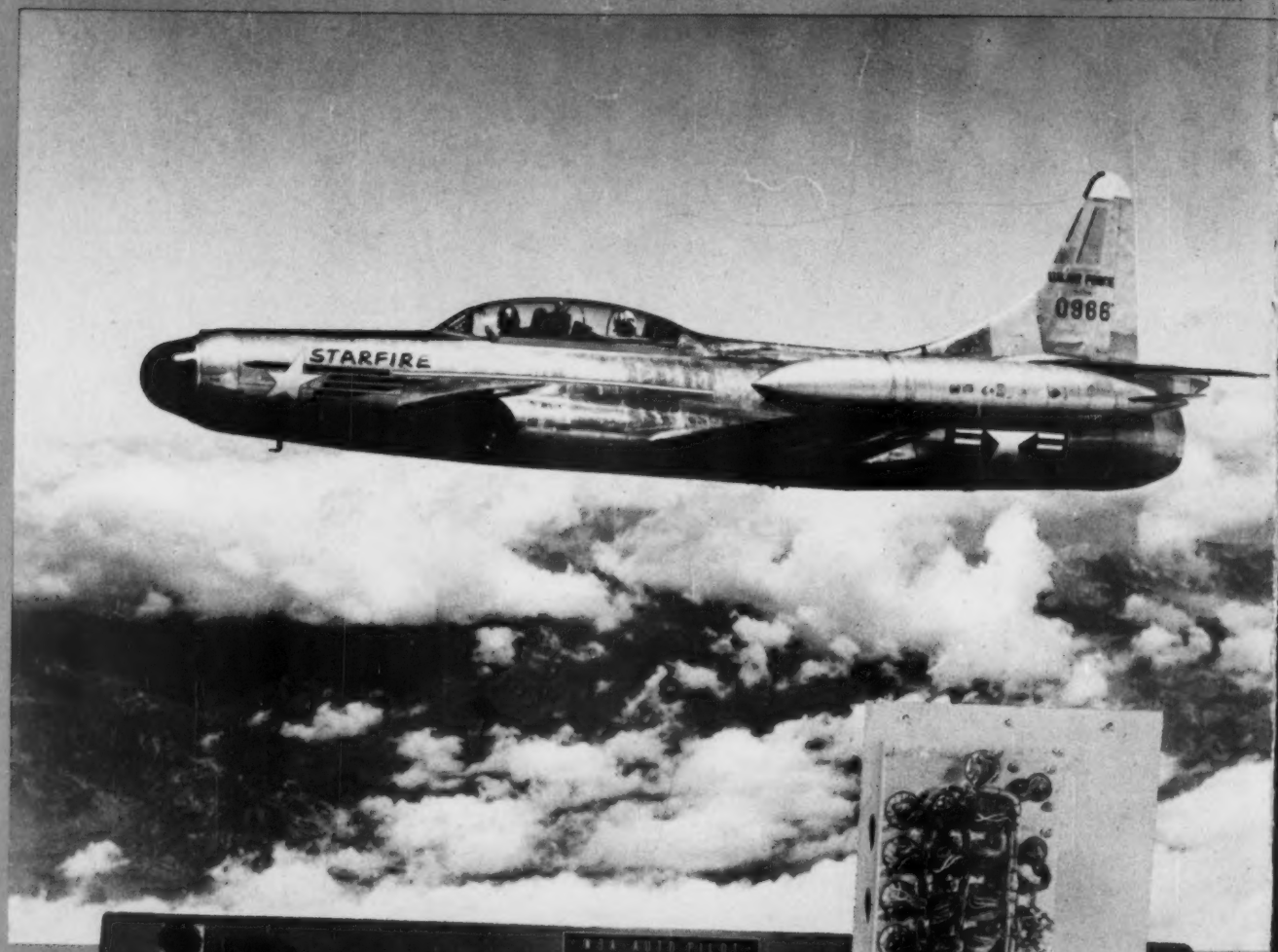
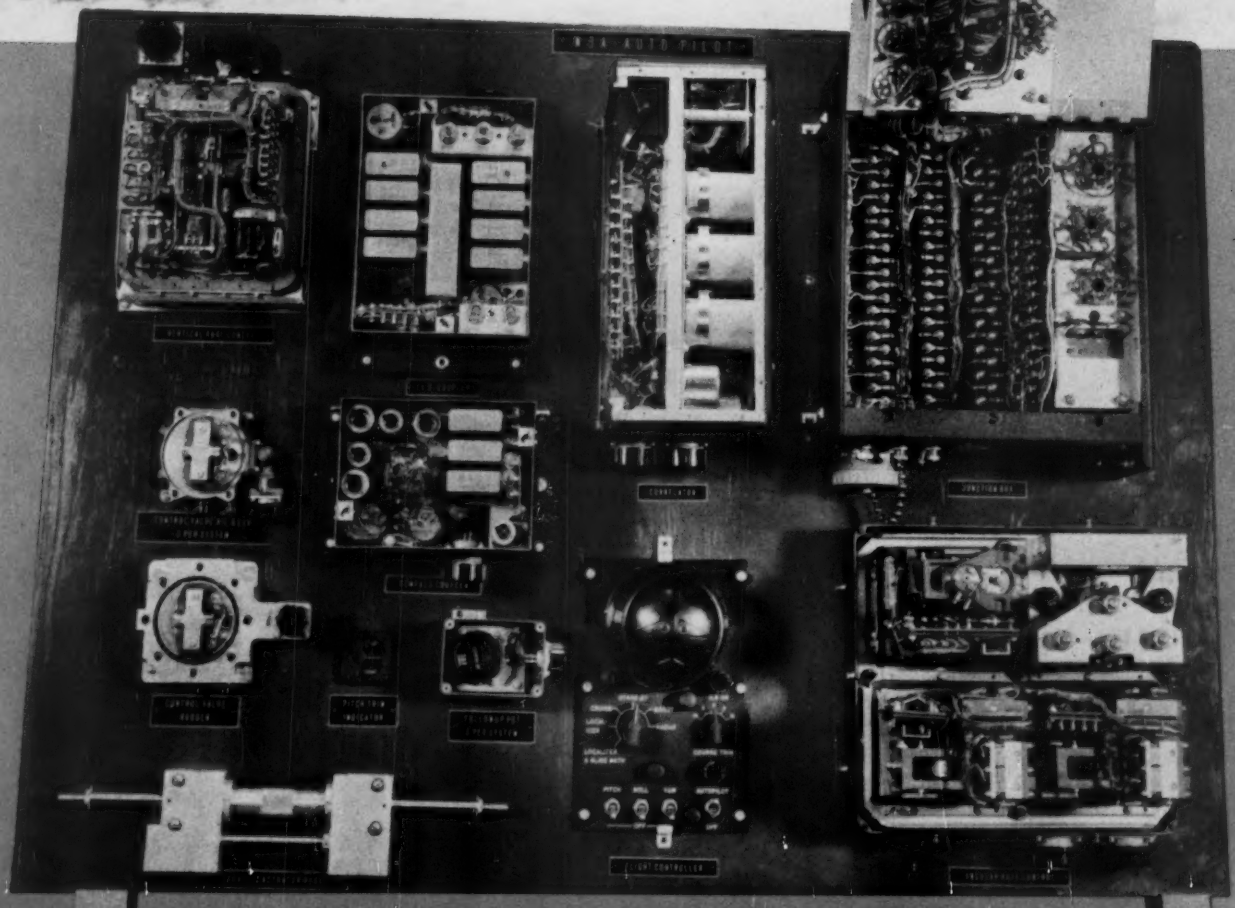
THE MORE that jet planes increase in speed, climbing ability, and in other aspects of performance, the more assistance must be given the pilot in the way of automatic controls. These devices—such as the Westinghouse autopilot—are almost as amazing as the planes themselves. This autopilot flies the plane automatically, whether cruising leisurely or on high-speed, fast maneuvering combat. Although the autopilot contains a few tubes, its operation is based primarily on the Magamp magnetic amplifier.

Among the airplanes making use of the autopilot is the Lockheed F-94C Starfire, most powerful of all single-engine jets now in production. It is a two-man aircraft, and, as described in the news releases, can climb to 45 000 feet or higher, and its speed is in the 600-mph class. After the "scramble," ground radar observers direct the airplane by radio toward the target. When near the target, the pilot turns on instruments that electronically track down the enemy, aim the airplane, and fire up to 24 rockets.

The Westinghouse autopilot is unique in the use of rapidly spinning "rate" gyroscopes as primary sensing elements for following the movements of the airplane during all maneuvers. They differ in this respect from ordinary "position" gyros, which are not locked to the airplane and hence resist any effort to change their direction of motion. Position gyros are sensitive only to changes in the attitude of the airplane, whereas the "rate" gyros of the Westinghouse autopilot respond only to the rate at which such changes take place. The autopilot is tied into the plane's radar and instrument landing system, helping it to track enemy targets automatically and to land in bad weather.

The autopilot is suitable for both large and small commercial airplanes as well as military aircraft. Radio-controlled, it can also serve to direct the flight of guided missiles and pilotless aircraft.

See back cover for pictures of the autopilot and Starfire.

Automatic Pilot

See story on inside back cover.